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16. ABSTRACT

This report describes the results of the following tests and evaluations of the Ames, Iowa, refuse processing plant during the year 1976: characterization of the refuse derived fuel (RDF) produced; equipment and plant performance evaluations; an analysis of plant maintenance and manpower requirements; and an analysis of plant operating costs. Also included is a brief summary of the boiler environmental emissions and boiler performance when mixtures of coal and RDF are burned. Complete discussion of the boiler emissions and performance will be available in separate reports. During the year the plant processed 37,136 Mg of municipal solid waste. Average as received heating value of the RDF produced was 13,050 kJ/kg at 23.0% moisture and 17.4% ash. The net cost of operating the refuse processing plant after credits were given for the RDF, recovered metals and dump fees was $18.90/Mg of municipal solid waste received. The economic model of the plant showed that a volume increase is the most attractive method of reducing the net cost.

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EVALUATION OF THE AMES SOLID WASTE RECOVERY SYSTEM

Part I - Summary of Environmental Emissions: Equipment, Facilities, and Economic Evaluations

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

The combination of the growing unacceptability of traditional methods of waste disposal along with the need to conserve the nation's resources has spurred efforts to exploit solid waste. The current energy shortage helped stimulate a further awareness that the high percentage of combustible material in solid waste represents an energy resource.

On August 30, 1975, the first continuous full-scale, solid waste recovery system for the processing and burning of municipal solid waste as a supplementary fuel for power generation commenced operation in the City of Ames, Iowa. This plant was designed using experience gained from the operation of the Environmental Protection Agency - City of St. Louis - Union Electric Company refuse demonstration plant.

This report provides the cumulative results of the Ames, Iowa refuse processing plant experience during its first full year of operation (1976). It provides basic data on the economics of operating the plant, the operating experience, and the characterization of refuse derived fuel, and will add to the knowledge required for future successful utilization of the resources contained in solid waste.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

This report describes the results of the following tests and evaluations of the Ames, Iowa, refuse processing plant during the year 1976: characterization of the refuse derived fuel (RDF) produced; equipment and plant performance evaluations; an analysis of plant maintenance and manpower requirements; and an analysis of plant operating costs. Also included is a brief summary of the boiler environmental emissions and boiler performance when mixtures of coal and RDF are burned. Complete discussion of the boiler emissions and performance will be available in separate reports. During the year the plant processed 37,136 Mg of municipal solid waste. Average as received heating value of the RDF produced was 13,050 kJ/kg at 23.0% moisture and 17.4% ash. The net cost of operating the refuse processing plant after credits were given for the RDF, recovered metals and dump fees was $18.90/Mg of municipal solid waste received. The economic model of the plant showed that a volume increase is the most attractive method of reducing the net cost.

This report was submitted in fulfillment of Grant No. R803903010 by the City of Ames under the sponsorship of the U.S. Environmental Protection Agency. Research studies were conducted by Iowa State University and Midwest Research Institute in cooperation with the Ames Laboratory, Energy, Research, and Development Administration. This report covers the period from February 1976 to February 1977.

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This report was prepared for the Environmental Protection Agency under Grant No. R803903010. It describes the work carried out by the Engineering Research Institute of Iowa State University and Midwest Research Institute concerning characterization of refuse derived fuel and performance and economic evaluations of the Ames, Iowa refuse processing plant.

This EPA sponsored program was directed by Mr. Carlton C. Wiles of the Municipal Environmental Research Laboratory, Solid and Hazardous Waste Research Division, Office of Research and Development and Mr. Robert Olexsey, Industrial Environmental Research Laboratory, Office of Energy, Minerals and Industry.

Dr. John C. Even, Dr. S. Keith Adams, and Mr. Petros Gheresus of the Industrial Engineering Department, Iowa State University, Professor Alfred W. Joensen and Dr. Jerry L. Hall of the Mechanical Engineering Department, Iowa State University, Mr. Charles A. Romine and Mr. Douglas E. Fiscus of Midwest Research Institute were the principal authors of this report. Many other Iowa State University personnel, Mr. Terry McKeighan, Mr. Kharoen Kosolcharoen, and Ms. Lari Larson of the Industrial Engineering Department, Iowa State University, assisted in compilation and analysis of the data.

Much of the laboratory analysis of the refuse samples and environmental emission samples was conducted by the ERDA - Ames Laboratory under the supervision of Dr. Velmer A. Fassel and Mr. Howard Shanks. Also, the conduct of these tests would not have been possible without the excellent cooperation and assistance provided by the City of Ames personnel; Mr. Arnold O. Chantland (Director of Public Works), Mr. J. Keith Sedore (Director, Electric Utility), Mr. Jerry Temple, Mr. Merlin Hove, Mr. Paul Hinderaker, Mr. Donald Riggs, Mr. Carl Baker, and Mr. Kenneth Moravetz.

SECTION 1

SUMMARY

The major observations regarding refuse derived fuel (RDF) characterization and economic evaluations made during the first year of the Ames study are highlighted in the following paragraphs.

In 1976 the refuse processing plant received 37,136 Mg of raw refuse. Of this amount, 7% was recovered Fe-metal scrap and 84% was RDF plus plant material loss. There appears to be no seasonal volume trend on a monthly basis with the possible exception of April having higher volume. The heating value of the RDF averaged 13,050 kJ/kg (as received heating value). In general, the Ames RDF is of a higher heating value than the RDF produced at St. Louis. A statistical analysis showed that although mean values were different, there was no difference in daily variability between Ames and St. Louis RDF. Some seasonal trends were observed. At Ames, the RDF moisture free heating value is lowest during the spring and summer months, and moisture content of RDF is highest during the spring months.

There is considerable variability in the bulk density, proximate and ultimate analysis and screen size of the Ames RDF. While the mean values of these constituents were different between RDF produced at Ames and that produced at St. Louis, there was no statistically significant difference in variability about the mean. The composition of RDF is just as variable from day to day, at least for the above named constituents, at Ames as it was at St. Louis. This result is a very important conclusion which could affect future material sampling programs at refuse processing plants.

The work force went through a "learning curve" in operating the refuse processing plant, storage bin and firing facility. However, except for a shredder bearing failure and two fires at the processing plant, the plant operated regularly and RDF was burned almost daily. The air classifier was a major maintenance area. During the study of electric power consumption it was discovered that the second stage shredder uses almost twice as much electric power as the first stage shredder. A major disappointment was the aluminum recovery system which produced only minor amounts of marketable aluminum scrap during 1976.

The net cost of operating the refuse processing plant (net cost of refuse disposal) for the total year 1976 was \$18.90/Mg of raw refuse received. This net cost is the cost after credits are given for the RDF, dump fees and recovered metals. Improvments in net cost can be achieved by reducing operating expenses and increasing the volume of raw refuse received. The economic model of the plant shows that volume increase is the most attractive method of reducing net cost. Improvements in the revenue received for recovered materials will occur in future years primarily due to a projected annual 10% to 15% increase in coal costs at Ames. This increase in fuel cost at the Ames Municipal Electric Utility will increase the credit given to RDF produced at the refuse processing plant. In future years there will undoubtedly be increases in such items as the cost of maintenance parts due to inflation and higher wage rates. However, the refuse processing plant has the capacity to process more than twice as much refuse as was processed during 1976. If additional large amounts of refuse can be obtained from nearby communities it is predicted that a dramatic reduction in the net cost of operating the refuse processing plant will result.

SECTION 2

INTRODUCTION

The grant for the first year of research was awarded February 5, 1976. The work plan was submitted in March 1976. Characterization of RDF was conducted March 17 through June 14, 1976. Boiler environmental emission sampling, boiler performance and boiler tube corrosion studies and economic evaluation of the refuse processing plant and the RDF firing facility commenced in June 1976. In addition, the City of Ames made available the results of their sampling and analysis of RDF heating value and moisture for the full year 1976.

Results and conclusions from the boiler environmental emission studies and the boiler performance and corrosion studies conducted on the two stoker boilers are being prepared in separate reports suitable for publication and will be available at a later date.

This final report of the first year's activities presents a summary of the environmental results and the results and conclusions from the economic evaluation of the resource recovery facility and the characterization of RDF produced.

Objectives of the portion of the research work reported in this report were as follows:

- Evaluate the stoker boilers for the effect on environmental emissions and boiler performance of burning coal plus RDF versus coal only.
- Evaluate the refuse processing plant monthly production records for possible trends and report the amount of refuse processed and the amount of recovered material.
- Characterize the RDF produced for bulk density, proximate and ultimate analysis, screen size, ash chemical composition, and ash fusion temperatures.
- Evaluate the operation of the resource recovery facility in terms of start-up experience, labor and maintenance required, power consumption, plant downtime and malfunction of equipment.

- Evaluate the capital investment required to build the resource recovery facility and evaluate the operating expense and revenues received from recovered materials.

The findings from the first year's evaluations and a discussion of the results and conclusions are presented in the following sections.

SECTION 3

SUMMARY OF ENVIRONMENTAL EMISSIONS AND PERFORMANCE OF THE STOKER-FIRED BOILERS

This section provides a synopsis of the major results and conclusions to date of the environmental emissions and boiler performance investigations on the stoker-fired steam generator units Nos. 5 and 6, at the City of Ames, Iowa.

Complete reports[1,2] of the environmental investigations, including analyses of the boiler bottom-ash, fuel inputs, and all of the test data are currently in the process of being prepared for publication. The analysis and interpretation of results, including statistical analysis is not yet complete, so the following excerpts must be considered preliminary.

POWER PLANT DESCRIPTION

Three boiler units, 5, 6, and 7, at the Ames Municipal Power Plant have been modified to burn solid waste as a supplemental fuel with coal. Boilers 5 and 6 are stoker-fired boilers and boiler 7 is a pulverized coal suspension-fired boiler. Because of boiler unit availability at the power plant, major research emphasis was on the environmental evaluation and boiler performance of the stoker-fired units Nos. 5 and 6 while firing coal and coal plus RDF. The characteristics of the two stoker-boiler units are summarized in Table 1.

EXPERIMENTAL DESIGN, SAMPLING LOCATIONS, AND ANALYTICAL METHODOLOGY

A block diagram showing the sample locations is included in Figure 1. All of the sampling was conducted on a regular basis according to the test summary of environmental sampling shown in Tables 2 and 3, except heavy organic species which were sampled on intermittent days as manpower, instrumentation, and equipment would allow.

Table 4 summarizes the sampling and analytical procedures used.

1/ Special Report - Part II, "Evaluation of the Stoker-Fired Steam Generators at the City of Ames, Iowa," (draft). EPA No. R803903-014.

2/ Special Report - Part III (with appendices), "Environmental Evaluation of the Stoker-Fired Steam Generators at the City of Ames, Iowa," (draft). EPA No. R803903-014, ERDA No. W-7405 ENG - 82.

TABLE 1. CHARACTERISTICS OF AMES MUNICIPAL POWER PLANT STOKER-FIRED STEAM GENERATORS

	Unit	
	5	6
Manufacturer	Riley	Union Iron Works
Electrical output - MW	7.5	12
Installation date	1951	1958
Pressure/temperature		
pKa/°C	4895/441	4999/441
(psi/°F)	(710/825)	(725/825)
Nominal steam output capacity		
kg/hr	43,100	56,700
(lb/hr)	(95,000)	(125,000)
Coal firing equipment	Spreader Stoker Traveling Grate	Spreader Stoker Traveling Grate
Furnace pressure	Balanced Draft	Balanced Draft
Dust collection equipment	Western Multiple Cyclone	American Blower Multiple Cyclone
Stack height		
meters	61	61
(feet)	(200)	(200)
Heat input at nominal capacity		
MJ/hr	154	202
(Btu x 10^6/hr)	(146)	(191)

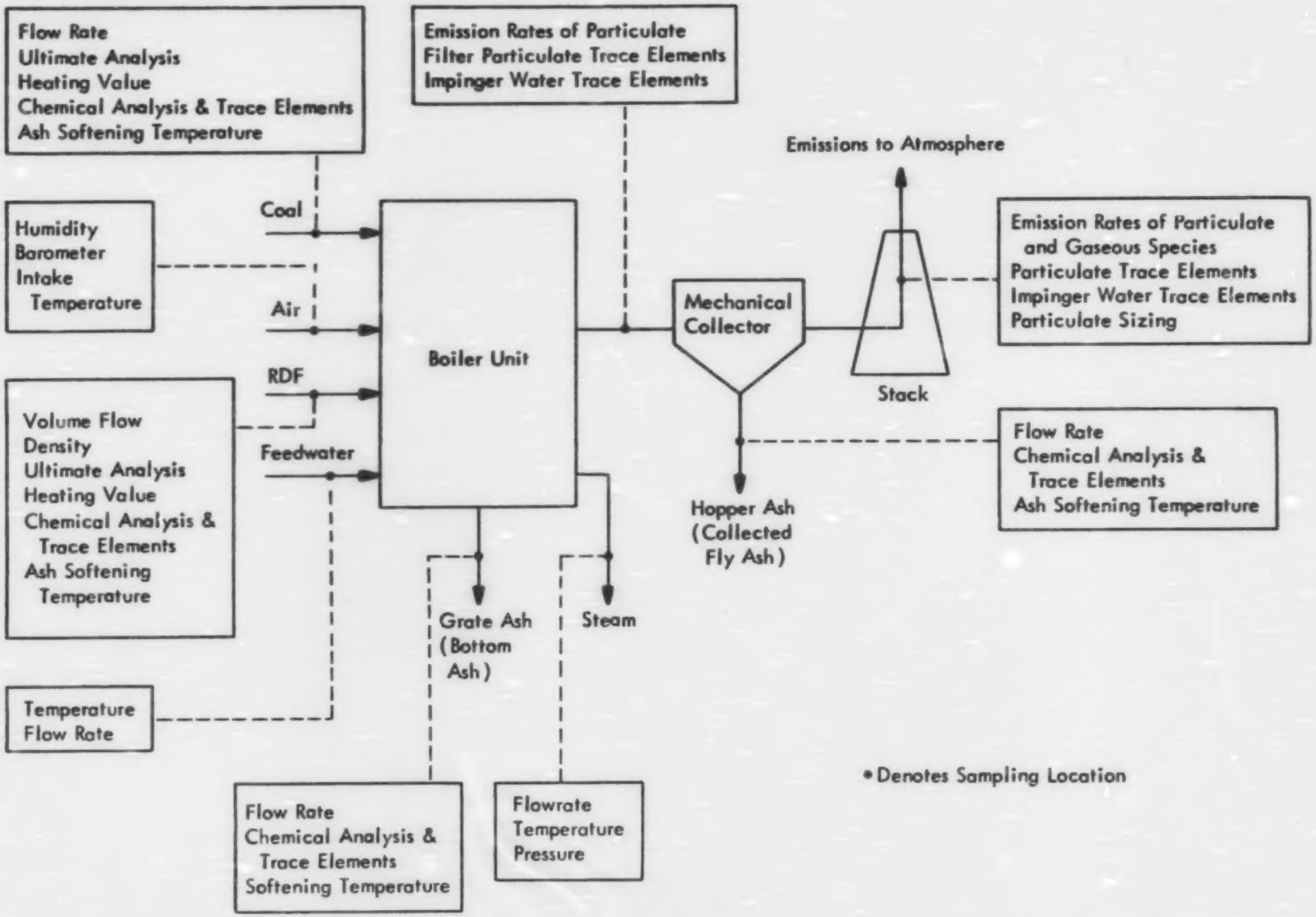
Flow Rate
Ultimate Analysis
Heating Value
Chemical Analysis & Trace Elements
Ash Softening Temperature
Emission Rates of Particulate
Filter Particulate Trace Elements
Impinger Water Trace Elements
Emissions to Atmosphere
Humidity
Barometer
Intake
Temperature
Coal
Air
RDF
Feedwater
Boiler Unit
Mechanical Collector
Stack
Emission Rates of Particulate and Gaseous Species
Particulate Trace Elements
Impinger Water Trace Elements
Particulate Sizing
Volume Flow
Density
Ultimate Analysis
Heating Value
Chemical Analysis & Trace Elements
Ash Softening Temperature
Hopper Ash (Collected Fly Ash)
Flow Rate
Chemical Analysis & Trace Elements
Ash Softening Temperature
Grate Ash (Bottom Ash)
Steam
Temperature
Flow Rate
•Denotes Sampling Location
Flow Rate
Chemical Analysis & Trace Elements
Softening Temperature
Flowrate
Temperature
Pressure

Figure 1. Boiler units nos. 5 and 6 sampling locations.

TABLE 2. SUMMARY OF EXPERIMENTAL DESIGN

(Numbers shown are test numbers referenced in the following Table 3.)

Stoker boiler No. 5
coal used: Iowa

% RDF \ % Load	60	80	100
0	4A, 4B	5	11
	20	16	31[b]
	36[a]	17	32[b]
20	8	6	7
	9A, 9B	12	14
	33	13	19
50	1	2	3
	34	10	18
	35	15	[c]

Stoker boiler No. 6
coal used: mixture of
50% Iowa, 50% Wyoming

% RDF \ % Load	80[d]
0	24
	29
	30
20	25
	26
	27
50	22
	23
	28

[a] Test 21 conducted while pulling ash from boiler to determine any change in performance and/or emissions due to ash removal.

[b] Bottom ash not weighed because of ash removal difficulties (slagging in boiler and clinkering of ash).

[c] Boiler No. 5 cannot operate at 100% steam load and 50% RDF without severe ash problems due to lack of excess air. Therefore, the third test in series was not conducted.

[d] Load was changed from the originally planned 100% to 80% steam load to be more typical of capability of boiler and air supply for refuse burning. This change was essential from experience gained during testing of Boiler No. 5.

TABLE 3. TEST SUMMARY OF ENVIRONMENTAL SAMPLING

Date	Unit	%Load	Fuel a/	%Refuse	Test Designation	Bottom Ash b/	Collector Ash	Particulate c/			Orsat		NO$_x$		SO$_x$		Aldehydes Ketones		Chlorides Org. Acids		Hg, Be, Se		Heavy Organics		HC & H$_2$O	
								BPC	S	Sizing	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S
6- 8-76	#5	60%	C+RDF	50%	EPA 1	✓	✓	✓	✓		✓	✓		✓		✓	✓		✓		✓					
6-10-76	#5	80%	C+RDF	50%	EPA 2	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓		✓	✓					
6-15-76	#5	100%	C+RDF	50%	EPA 3	✓	✓	✓	✓		✓	✓	✓		✓		✓		✓		✓	✓				
6-17-76	#5 B-B d/	60%	C	0%	EPA 4d/ A & B	✓✓	✓✓	✓✓	✓✓		✓✓	✓✓	✓✓		✓✓		✓✓		✓✓			✓✓				
6-21-76	#5	80%	C	0%	EPA 5	✓	✓	✓	✓		✓	✓		✓		✓		✓		✓		✓				
6-23-76	#5	80%	C+RDF	20%	EPA 6	✓	✓	✓	✓		✓	✓		✓		✓		✓		✓		✓				
6-25-76	#5	100%	C+RDF	20%	EPA 7	✓	✓	✓	✓		✓	✓		✓		✓		✓		✓		✓		✓		
6-28-76	#5	60%	C+RDF	20%	EPA 8	✓	✓	✓	✓		✓	✓		✓		✓		✓		✓		✓				
6-30-76	#5 B-B d/	60%	C+RDF	20%	EPA 9d/ A & B	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓		✓✓		✓✓		✓✓		✓✓		✓✓				
7- 2-76	#5	80%	C+RDF	50%	EPA 10	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
7- 6-76	#5	100%	C	0%	EPA 11	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓		✓		✓
7- 8-76	#5 B-B d/	80%	C+RDF	20%	EPA 12d/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
7- 8-76	#5 B-B d/	80%	C+RDF	20%	EPA 13d/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
7-16-76	#5	100%	C+RDF	20%	EPA 14	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
7-17-76	#5	80%	C+RDF	50%	EPA 15	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
7-19-76	#5 B-B d/	80%	C	0%	EPA 16d/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
7-19-76	#5 B-B d/	80%	C	0%	EPA 17d/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
7-23-76	#5	100%	C+RDF	50%	EPA 18	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
7-24-75	#5	100%	C+RDF	20%	EPA 19e/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓	TEST ABORTED - BOILER COULD NOT HOLD LOAD									
8- 2-76	#5 B-B d/	60%	C	0%	EPA 20d/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8- 2-76	#5 B-B d/	60%	C	0%	EPA 21d,f/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
7-26-76	#5	60%	C+RDF	50%	EPA 1-Supp.	--	--	--	-	✓	--	-		-		-	TEST ABORTED - RAIN					--				--

(continued)

TABLE 3. (continued)

Date	Unit	%Load	Fuel a/	%Refuse	Test Designation	Bottom Ash b/	Collector Ash	Particulate c/			Orsat		NO$_x$		SO$_x$		Aldehydes Ketones		Chlorides Org. Acids		Hg, Be, Se		Heavy Organics		HC & H$_2$O	
								BPC	S	Sizing	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S	BPC	S
8- 5-76	#6	80%	C+RDF e/	50%	EPA 22	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8- 6-76	#6	80%	C+RDF	50%	EPA 23	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8- 9-76	#6	80%	C	0%	EPA 24	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-10-76	#6	80%	C+RDF	20%	EPA 25	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-11-76	#6	80%	C+RDF	20%	EPA 26	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-12-76	#6	80%	C+RDF	20%	EPA 27	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-13-76	#6	80%	C+RDF	50%	EPA 28	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-16-76	#6	80%	C	0%	EPA 29	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-18-76	#6	80%	C	0%	EPA 30	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				✓
8-24-76	#5 B-B d/	100%	C	0%	EPA 31 e/	✓ g/	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
8-24-76	#5 B-B d/	100%	C	0%	EPA 32 e/	✓ g/	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
8-25-76	#5	60%	C+RDF	20%	EPA 33	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
8-26-76	#5 B-B d/	60%	C+RDF	50%	EPA 34 e/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
8-26-76	#5 B-B d/	60%	C+RDF	50%	EPA 35 e/	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				
8-27-76	#5	60%	C	0%	EPA 36	✓	✓ wt	✓	✓	✓	✓	✓		✓		✓		✓		✓		✓				

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a/ Coal for tests on Boiler No. 5 is Iowa coal; on No. 6, 50% Wyoming and 50% Iowa coal.
b/ Bottom Ash and Collector Ash weighed together after completion of test and removal of ash to ash silo except where special weights are noted.
c/ BPC - Before Particulate Collector; S = Stack; Sizing = Sizing on stack.
d/ B-B indicates back-to-back testing.
e/ Boiler load dropped and test terminated early.
f/ Test conducted while pulling ash to determine if boiler performance and emissions change when ash is pulled.
g/ Bottom ash not weighed due to ash removal difficulties.

TABLE 4. SUMMARY OF SAMPLING AND ANALYTICAL PROCEDURES FOR BOILER ENVIRONMENTAL EMISSIONS

	Sampling technique	Analytical procedure
Fuel into boiler · Coal · RDF	Hourly samples combined to form single composite sample	· Trace elements via x-ray fluorescence (XRF) · Ash via ASTM method · Moisture via ASTM method · HHV via ASTM method
Combustion · Air	Thermometry	· Wet bulb and dry bulb temperature
Ash · Grate (bottom ash) · Collected fly ash (hopper ash)	Grab samples combined to form single composite sample	· Trace elements via x-ray fluorescence (XRF) or appropriate ASTM method · Ash via ASTM method · Moisture via ASTM method · HHV via ASTM method · Trace elements in grab sample composite taken from particulate collector hopper ash)
Steam	-	· Flow rate · Temperature · Pressure
Fly ash · Before particulate collector · Stack	Andersen impactor EPA Method 5	· Size distribution via impactor (stack only) · Trace elements in material o on filter via XRF · Trace elements in impinger solutions via an Inductively Coupled Plasma Analytical System (ICP)

(continued)

TABLE 4. (continued)

	Sampling technique	Analytical procedure
Flue gas	Orsat	. CO_2, CO, O_2, N_2
. Stack	EPA Method 7	. NO_x
	EPA Method 6	. SO_2
	Modified EPA Method 5	. Aldehydes and ketones via method of Carotti and Kaiser
	Modified EPA Method 5	. Organic acid via ion chromatograph . Cyanide via ion selective electrode . Phosphorus via spectrophotometer
	Modified EPA Methods 5 and 6	. Chlorides via colorimetric and spectrophotometric analysis of part of impinger solutions from SO_x and cyanide train
	Modified EPA Method 5	. Mercury, arsenic, antimony and beryllium via ICP
	Grab sample	. C_1 and C_5 hydrocarbons via gas chromatography
	Aspiration across column of macro-reticular resin	. Organics (PCB, POM, etc.) via gas chromatograph-mass spectrograph (intermittent days)

BOILER PERFORMANCE

RDF in combination with coal was successfully fired in the stoker boilers with some difficulty but with no major problems. A high refuse fuel utilization rate was encountered. There was no significant direct effect of burning RDF on the measured boiler thermal efficiency. There was no significant difference in the percent of the heat input leaving as combustibles in the ash, the average being approximately 5% for both coal and RDF. However, based on the current method of RDF injection, high excess air flow rates were encountered which resulted in an indirect effect on boiler thermal efficiency. The RDF pneumatic feeders and the additional over fire air increased the secondary air (excess air) supplied. The increase in excess air required to burn RDF reduced the boiler thermal efficiency. There was general consensus among the boiler operators that more combustion air through the grate is necessary when firing RDF to prevent slagging and to maintain a proper fire bed.

Ultimate fouling of the superheater section of boiler No. 5 was experienced. Calculation of the fuel fouling index correlates with this behavior. The most significant influence is the higher sodium content of RDF which has a detrimental effect on the fouling index. Soot blowers will be installed to reduce this fouling behavior. In addition, an alternate method of RDF injection might reduce this effect.

At most boiler loads, bottom ash tended to increase somewhat and fly ash tended to decrease with increasing percent RDF.

Ash fusion temperatures of RDF are typically 60 to 100°C lower than for coal. However, no specific correlation of boiler performance to ash fusion temperatures has been determined.

ENVIRONMENTAL EMISSIONS

In coal plus RDF firing applications, there are a variety of air pollution control devices that could be used, such as multiple cyclones, scrubbers and electrostatic precipitators. Therefore, the change in uncontrolled emissions due to burning RDF is of great interest to the designer of future refuse burning installations. The following discussion presents a summary of the uncontrolled emissions due to burning coal only and to burning coal plus RDF.

Excess air before the particulate collector (BPC) particulate, stack particulate, particulate collector efficiency, stack particle size distribution, NO_x, SO_x, chloride, formaldehyde, cyanide and phosphate emission rates, all as functions of RDF input, are given in Figures 2 through 11, respectively.

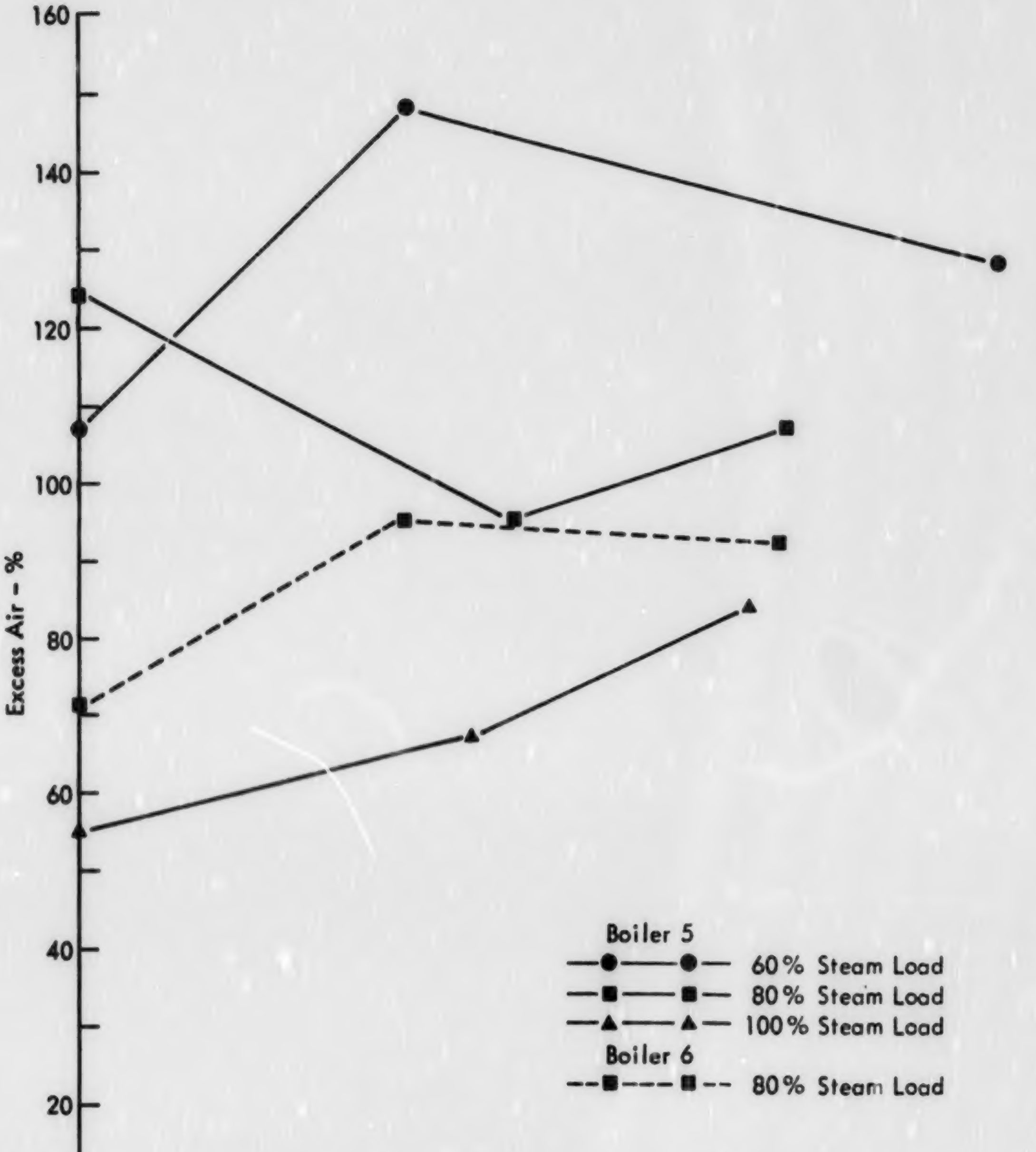


Figure 2. Percent excess air as a function of RDF heat input.

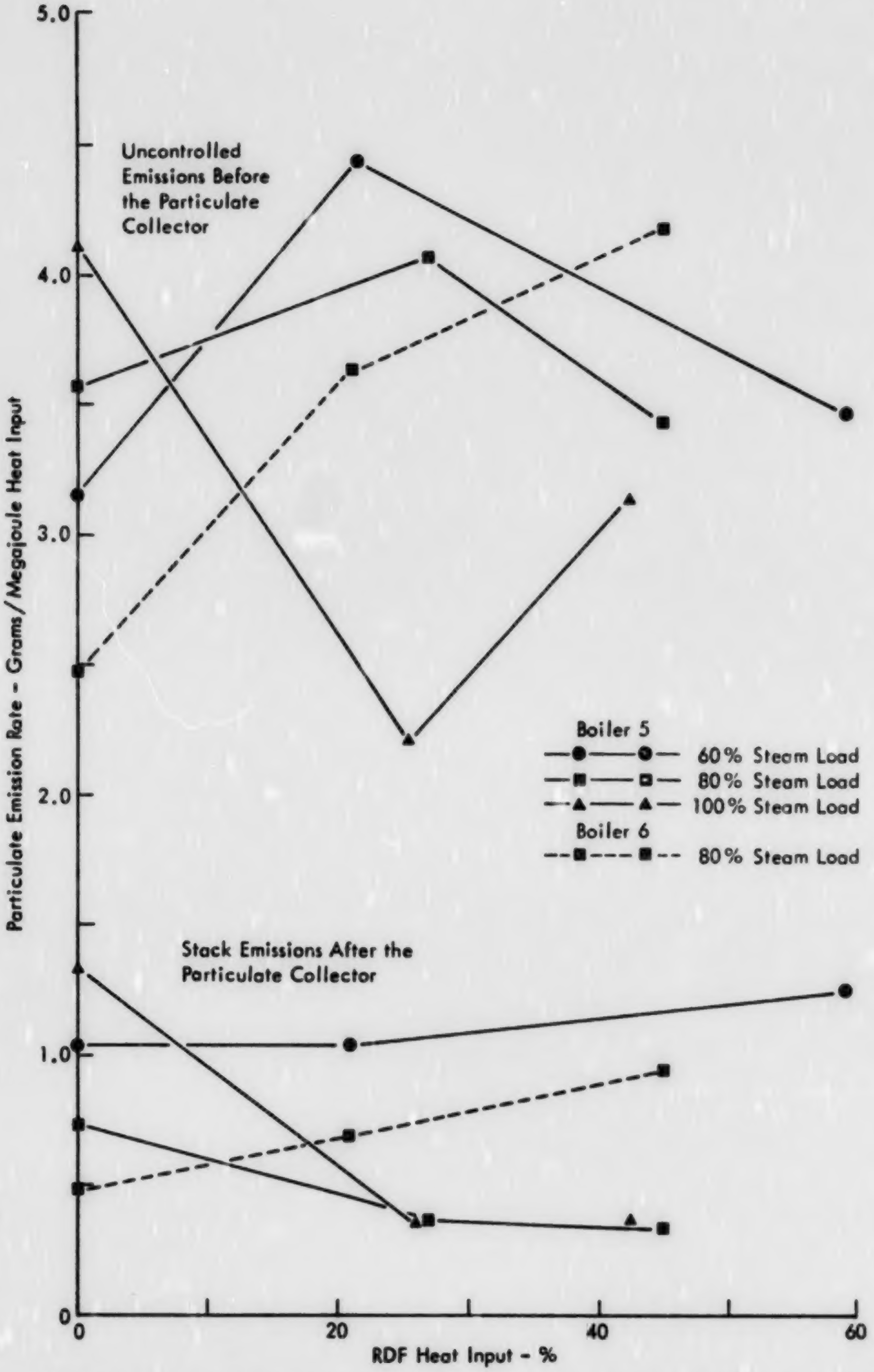


Figure 3. Particulate emissions as a function of RDF heat input.

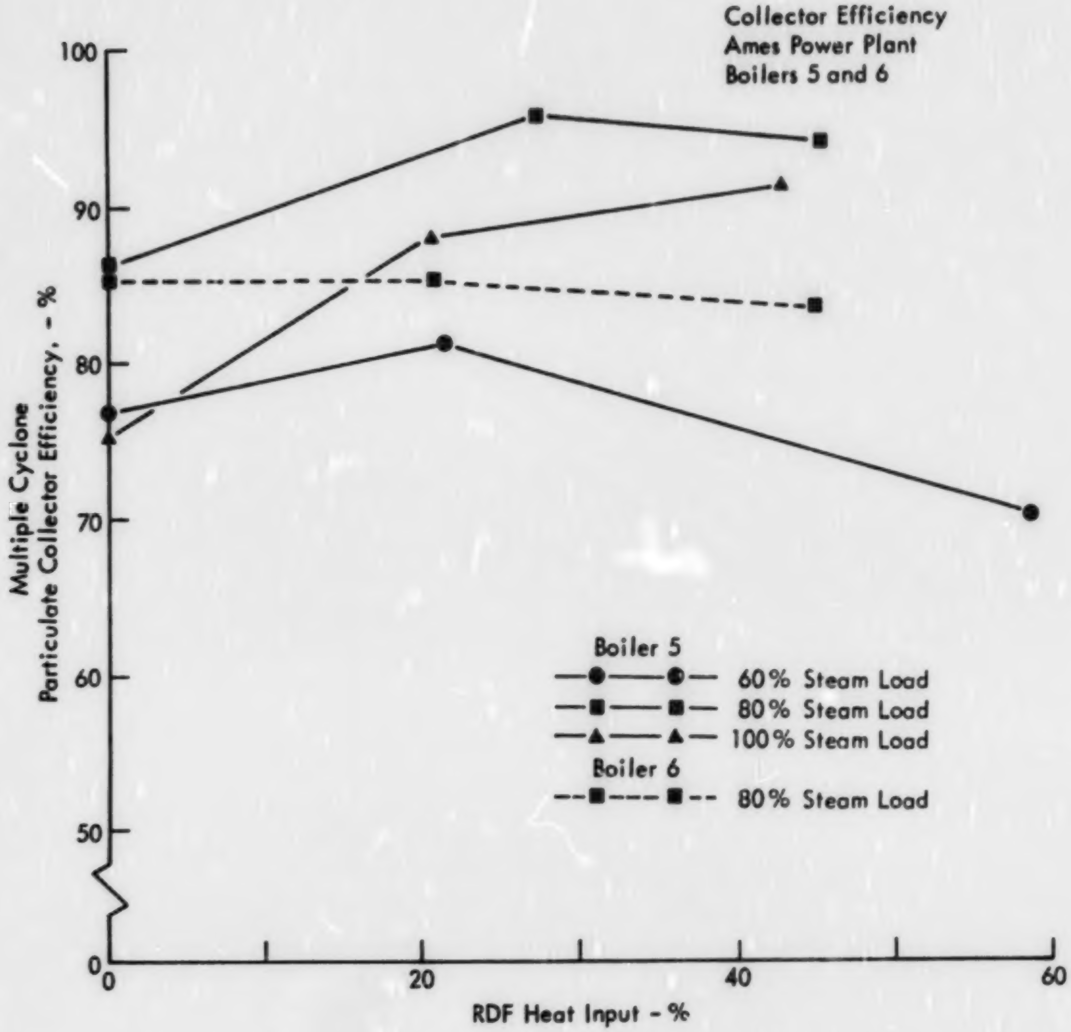
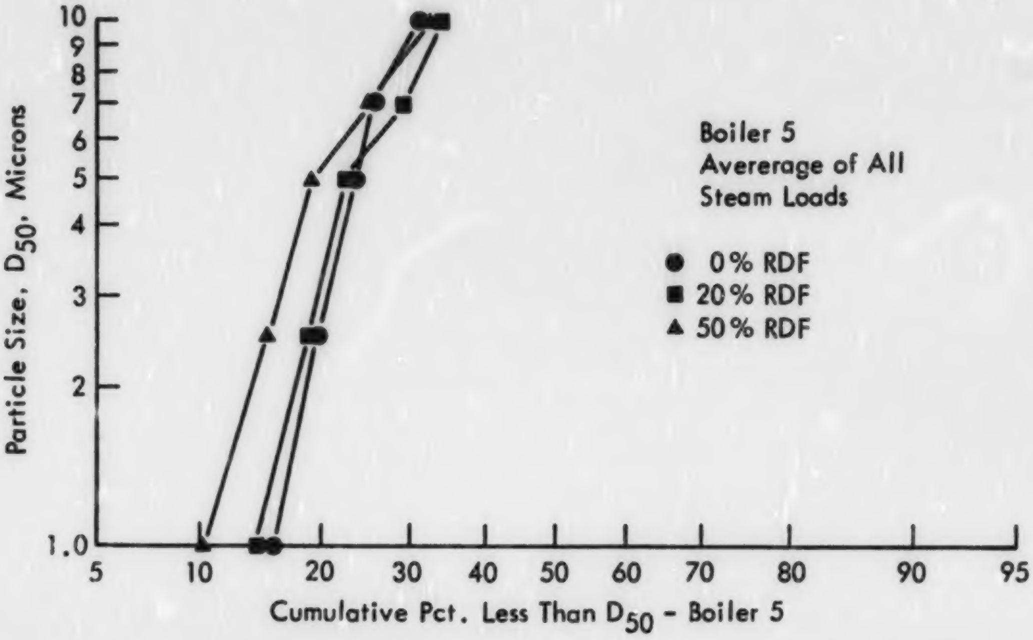


Figure 4. Particulate collector efficiency as a function of RDF heat input.



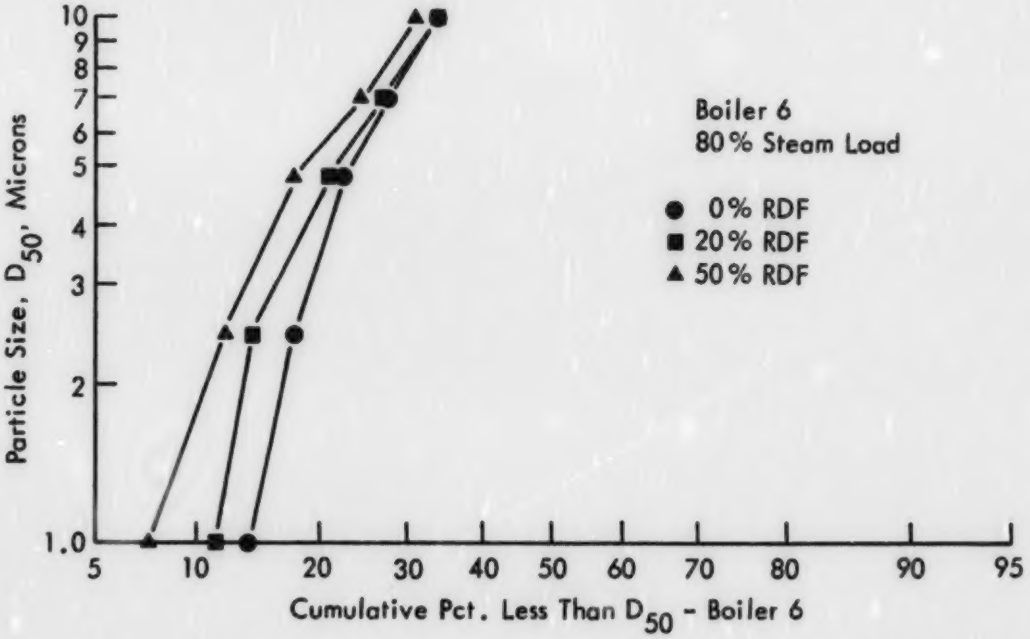


Figure 5. Cumulative particle size distribution of stack emissions as a function of RDF heat input.

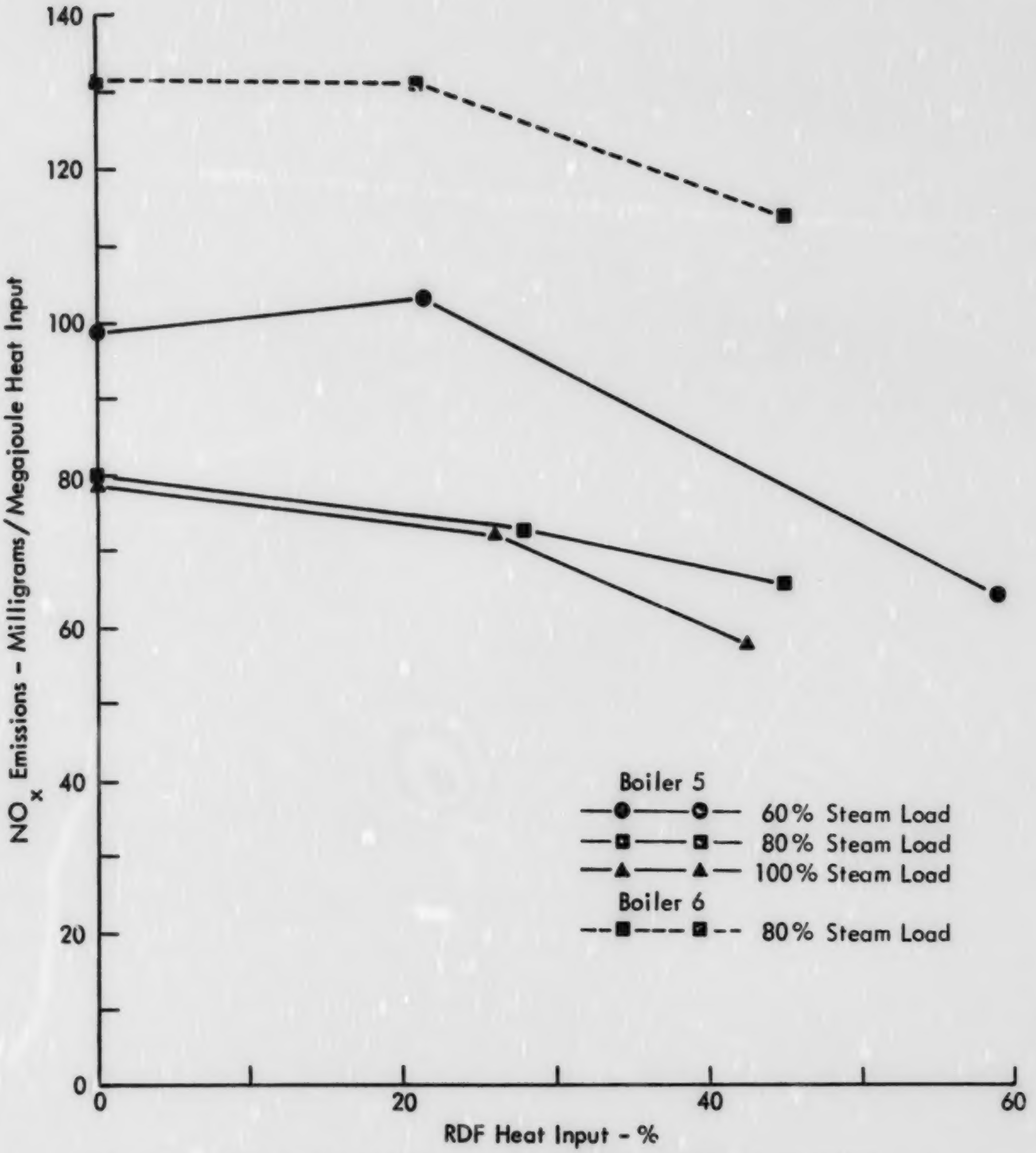


Figure 6. NO_x stack emissions as a function of RDF heat input.

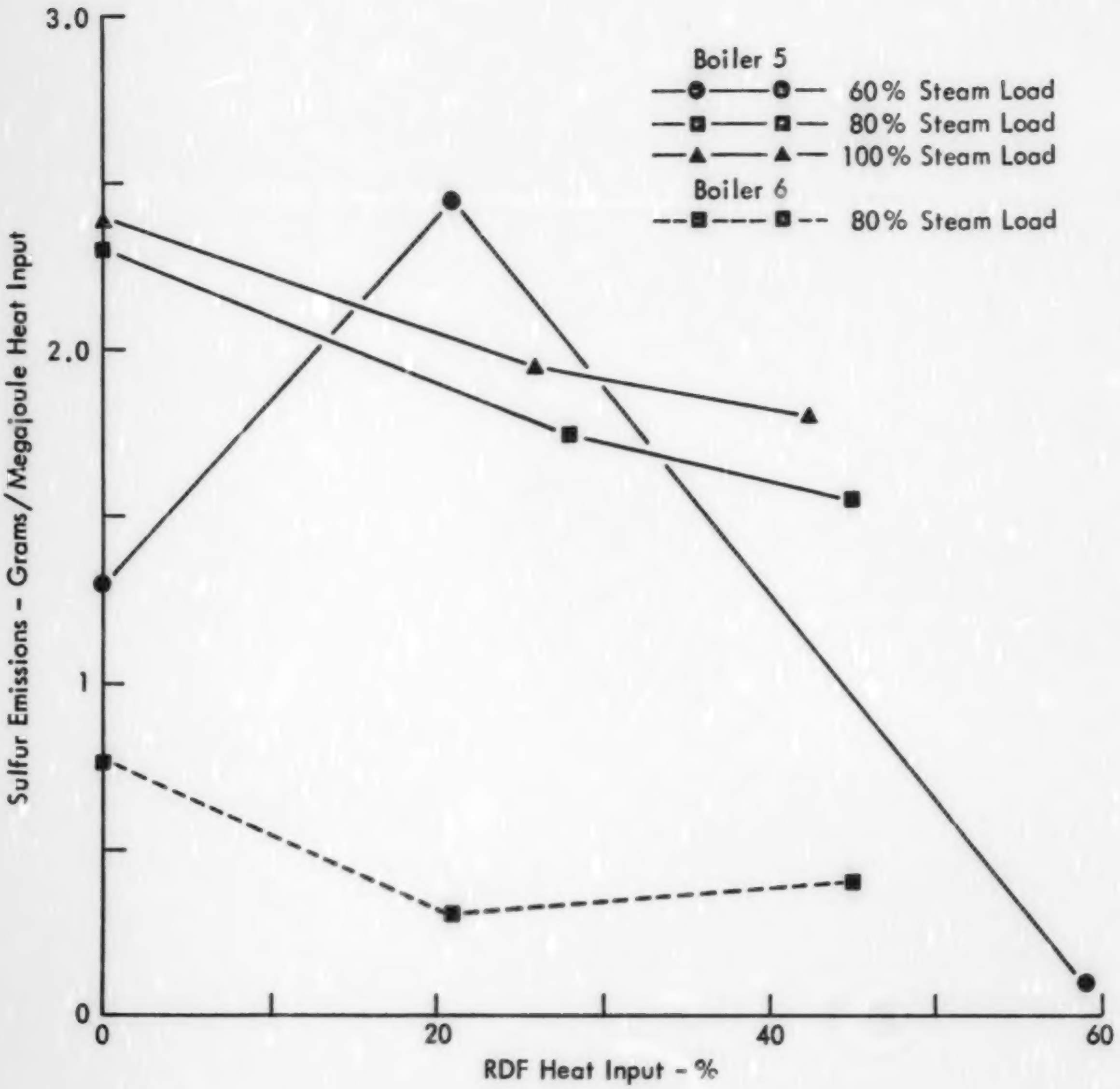


Figure 7. Sulfur stack emissions as a function of RDF heat input.

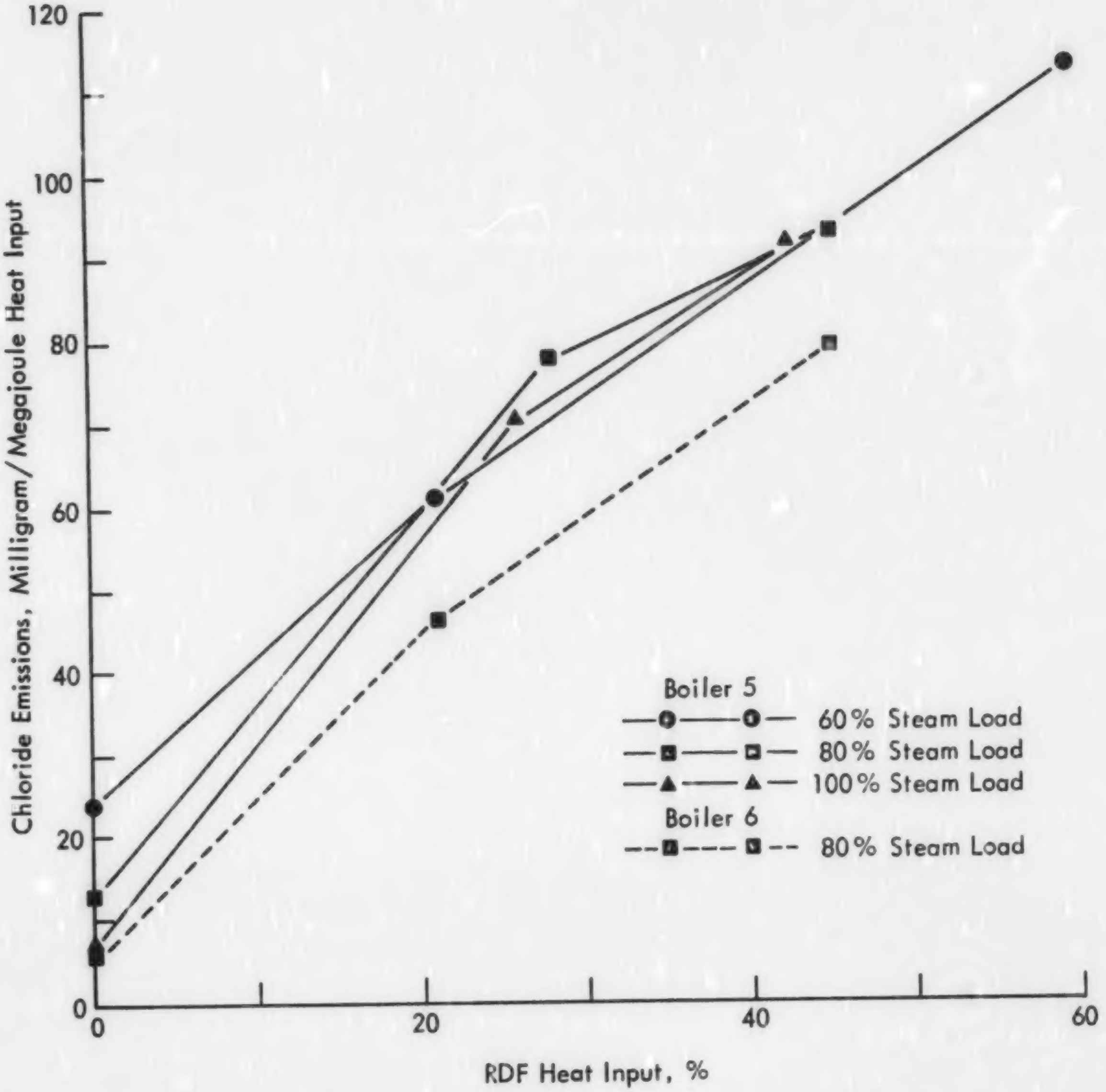


Figure 8. Chloride stack emissions as a function of RDF heat input.

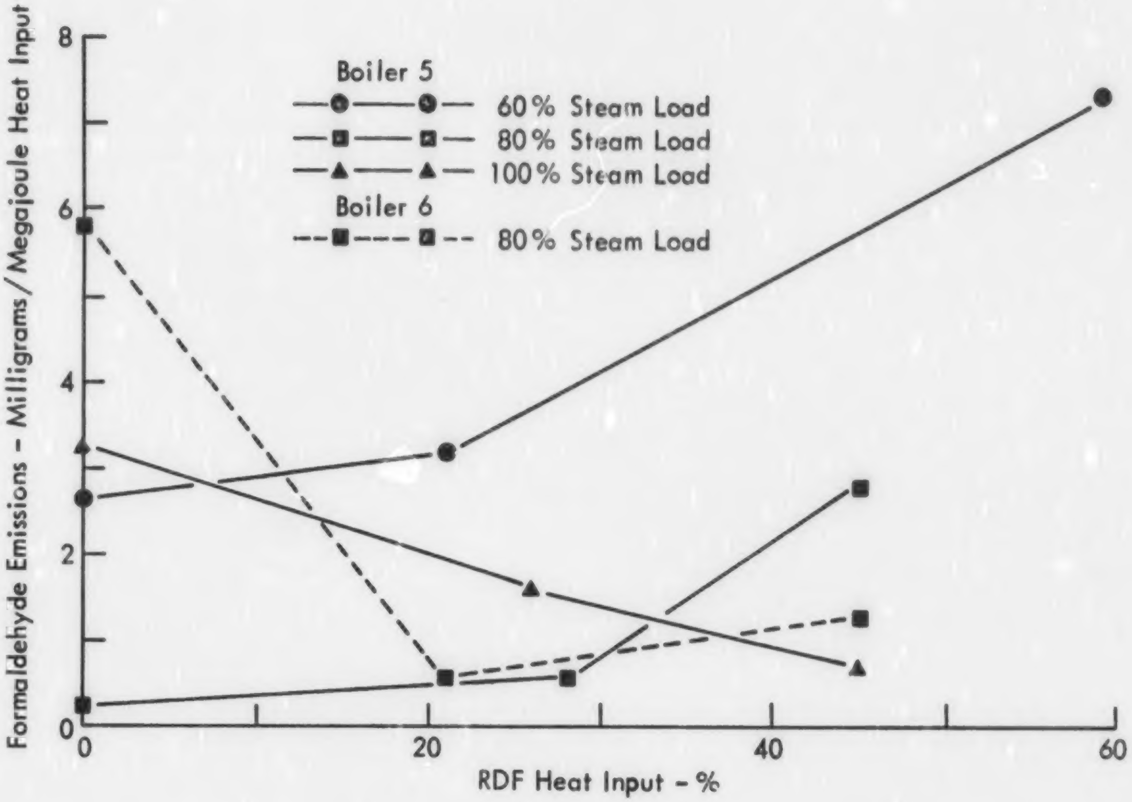


Figure 9. Formaldehyde stack emissions as a function of RDF heat input

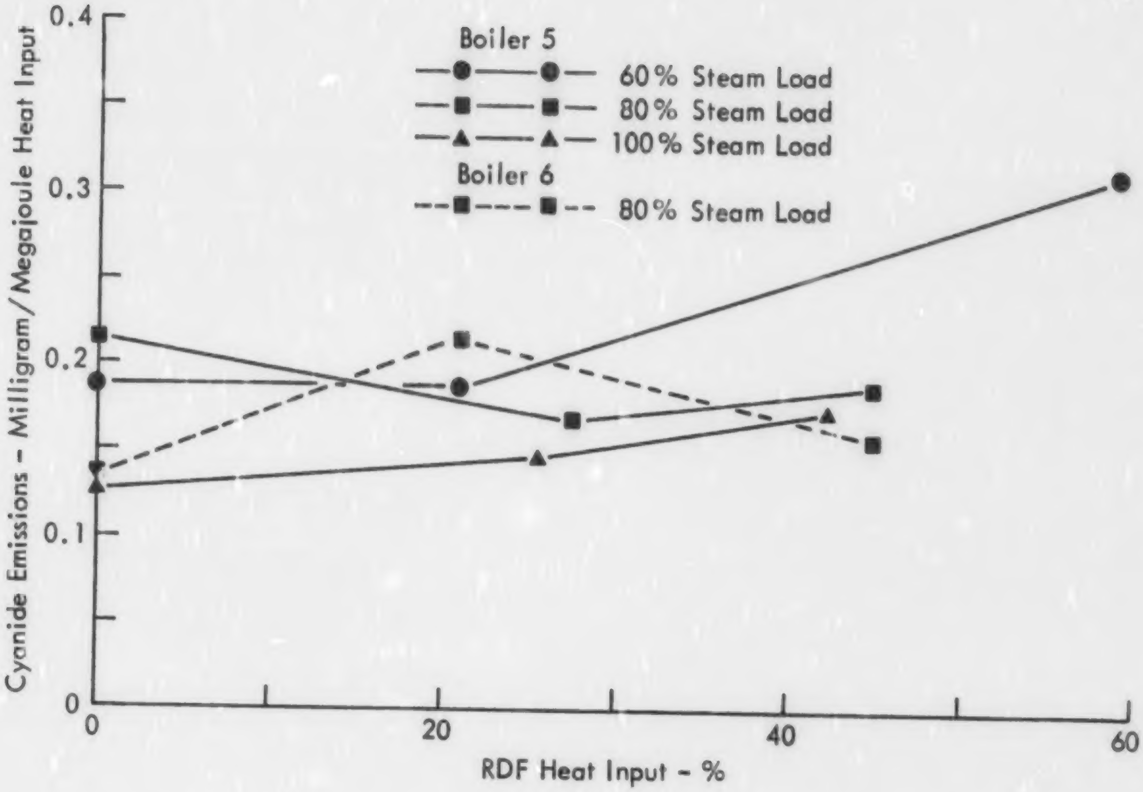


Figure 10. Cyanide stack emissions as a function of RDF heat input.

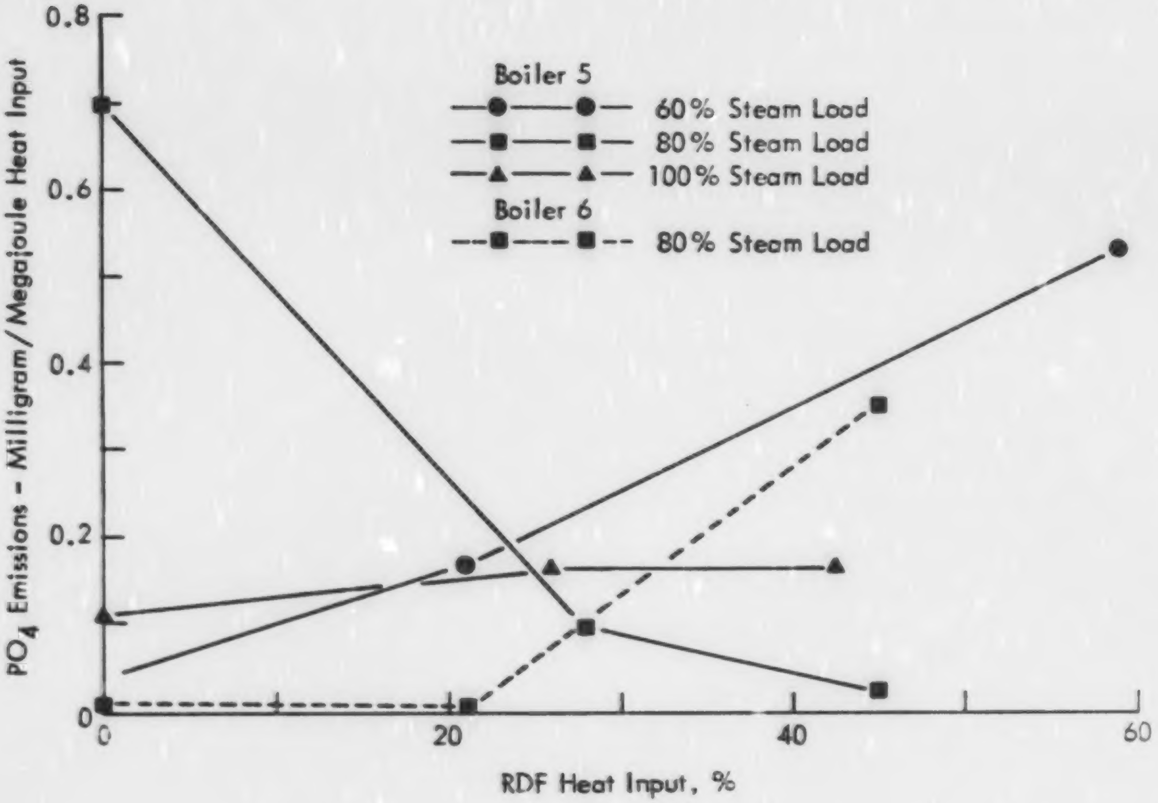


Figure 11. Phosphate stack emissions as a function of RDF heat input.

In addition, organic compounds in stack emissions and trace elements in BPC particulate (fly ash) are given in Tables 5 and 6, respectively.

TABLE 5. ORGANIC COMPOUNDS IN STACK EMISSIONS

Compound	Stack gases ($\mu g/1,000\ m^3$)	Particulates (ng/g)
Naphthalene	BDL[a]	BDL
Acenaphthalene	BDL	BDL
Fluorene	36.5	BDL
Anthracene	BDL	BDL
Fluoranthene	119	BDL
Pyrene	36.5	BDL
Benzofluorenes (1,2 and 2,3)	54.7	BDL
1,2-Benzanthracene	BDL	BDL
a- and e-Benzyprenes and perylene	72.9	0.42
20-Methylcholanthrene	BDL	BDL
Dibenzanthracenes (1,2-3,4 and A,H)	BDL	BDL
Dibenzanthracene (2,3-6,7)	BDL	BDL
Coronene and 3,4-9,10 dibenzopyrene	BDL	BDL
Aliphatic hydrocarbons	31,700	340
Detection limits	35 $\mu g/1,000\ m^3$	0.35 ng/g

[a] BDL - Below detection limit.

TABLE 6. CALCULATED[a] TRACE ELEMENTS IN UNCONTROLLED PARTICULATES

Element		Concentration (mg/MJ) for boiler No. 5 and 100% load 0% RDF	 20% RDF	 50% RDF
Aluminum	Al	306	104	106
Potassium	K	50.4	32.2	24.6
Calcium	Ca	374	176	216
Titanium	Ti	15.7	8.74	10.79
Vanadium	V	2.65	1.21	1.31
Chromium	Cr	0.822	0.375	0.553
Iron	Fe	398	150	181
Nickel	Ni	0.368	0.121	0.099
Copper	Cu	0.375	0.376	0.598
Zinc	Zn	13.8	13.3	11.2
Gallium	Ga	0.55	0.49	0.34
Germanium	Ge	1.5	0.39	0.20
Arsenic	As	0.57	-	-
Selenium	Se	0.056	0.037	0.039
Rubidium	Rb	0.406	0.0724	0.1012
Strontium	Sr	1.36	0.362	0.451
Lead	Pb	8.71	13.6	9.61

[a] Calculated from sum of stack emission particulates and collected fly ash.

All values reported in Tables 5 and 6 and Figures 2 through 11 are averages of results from the test replications of each boiler load and percent RDF. The number of replications for each test condition is shown in Table 2.

Table 6, trace element analysis of the uncontrolled particulate emissions, was devised by combining the analysis of the stack emission particulates and the analysis of the fly ash samples from mechanical particulate collector ash hoppers.

The results show trends based on calculated averages. The decision as to whether or not these trends are statistically significant must wait until the ongoing statistical analysis of the results is complete. Also, at 100% steam load and 50% RDF, boiler No. 5 experienced a lack of combustion air due to insufficient induced draft fan capacity with resulting boiler operational problems. Therefore, this test condition may not be typical of normal boiler operation.

No significant hydrocarbon emissions in the C_1 to C_5 range have been found to date. Results from the organic acids analysis and the mercury train are not yet available.

Both uncontrolled particulate emissions before the particulate collector and stack particulate emissions to the atmosphere did not have clear overall trends as a function of RDF heat input. Particulate emissions either increased with percent RDF depending on boiler unit and boiler load. Particulate collector efficiency initially increased with increasing percent RDF then decreased with additional RDF input. While no particulate sizing was done before the particulate collector, it is believed that the particles in the flue gas are larger when burning RDF. Therefore, the multiple cyclone particulate collector efficiency increases with increased RDF. However, the increased air flows with RDF help carry more particulate through the collector, thus decreasing its efficiency after optimum flow rate is reached.

NO_x and sulfur emissions both have trends of decreasing emissions with increased percent RDF. The major exception is sulfur emissions for boiler No. 5 at 60% steam load and 20% RDF. This condition had sulfur emissions comparable to coal only at higher boiler steam loads. The reason for this high sulfur emission at this test condition is believed to be due to an unusually high amount of sulfur in the coal for this particular test.

During these tests, boiler No. 5 used Iowa coal only. Boiler No. 6 used a mixture of one-half Iowa and one-half Wyoming coal. Wyoming coal is lower in sulfur content than Iowa coal and thus sulfur emissions for boiler No. 6 are lower, and the effect of RDF is not as pronounced.

Chloride emissions increased with increasing percent RDF for all boiler loads. Chloride emissions were substantially lower for coal only than for coal plus RDF, being approximately 0.02 g/megajoules or less. The coal plus RDF emissions therefore appear to be a function of the chlorine in the RDF.

Formaldehyde, cyanide, and phosphate emissions were quite variable, with no clear trends of emissions as a function of percent RDF. Emissions at 20% RDF were either lower, or only slightly higher than the coal only emissions, the major exception being cyanide emissions from boiler No. 6 which showed a relatively sharper increase in emissions at 20% RDF than for the other test conditions. However, at 50% RDF, the increases and decreases from the 20% RDF test condition were variable enough to make it difficult to establish a trend based on percent RDF.

The heavy organic compounds in the stack emissions are shown in Table 5. Many of the heavy organic compounds analyzed were below the laboratory detection level and the majority of the organics found were in the stack gases and not in particulate form. These data are the results of only two stack samples performed to assess the potential presence of such compounds. Therefore, no comparisons of emissions as a function of percent RDF can be made at this time.

Table 6 presents the trace element analysis for the uncontrolled particulates (BPC fly ash) as a function of percent RDF. There were increases due to burning RDF in only two of the 19 elements analyzed. Only copper and lead showed increases.

SECTION 4

REFUSE PROCESSING PLANT MONTHLY PRODUCTION

The amount of refuse processed during the year 1976 and the amount of RDF and recovered materials derived from this raw refuse are summarized below:

	Mg	%
Raw refuse processed	37,136.53	100.0
RDF (by difference)[a]	31,261.08	84.18
Fe-metal	2,594.69	6.99
Non Fe-metal	4.67	0.01
Wood chips	295.69	0.79
Glass and grit	217.30	0.59
Rejects to landfill	2,763.10	7.44

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[a] Raw refuse less Fe-metal, non-Fe-metal, wood chips, glass and grit, and rejects to landfill. Includes any plant material loss.

Appendix Tables A-1 and A-2 contain the monthly production records in terms of actual weight and the conversion to percentages.

Figure 12 is a graphical presentation of the monthly amount of raw refuse received. The month of November is low because of 10 days of lost production due to a fire at the processing plant. There is little variation from month to month in the amount of raw refuse received except that April is higher than any of the other months. Whether or not this is a seasonal trend due to spring cleaning, etc., will be verified by comparison to monthly volume in future years.

The two major volumes of products produced by the refuse processing plant were RDF and ferrous metal scrap. Figure 13 shows the amount of RDF and ferrous metal as a percent of the raw refuse received. There is little variation in the monthly percentages. The plant is operating consistently in terms of the amount of these two major products produced.

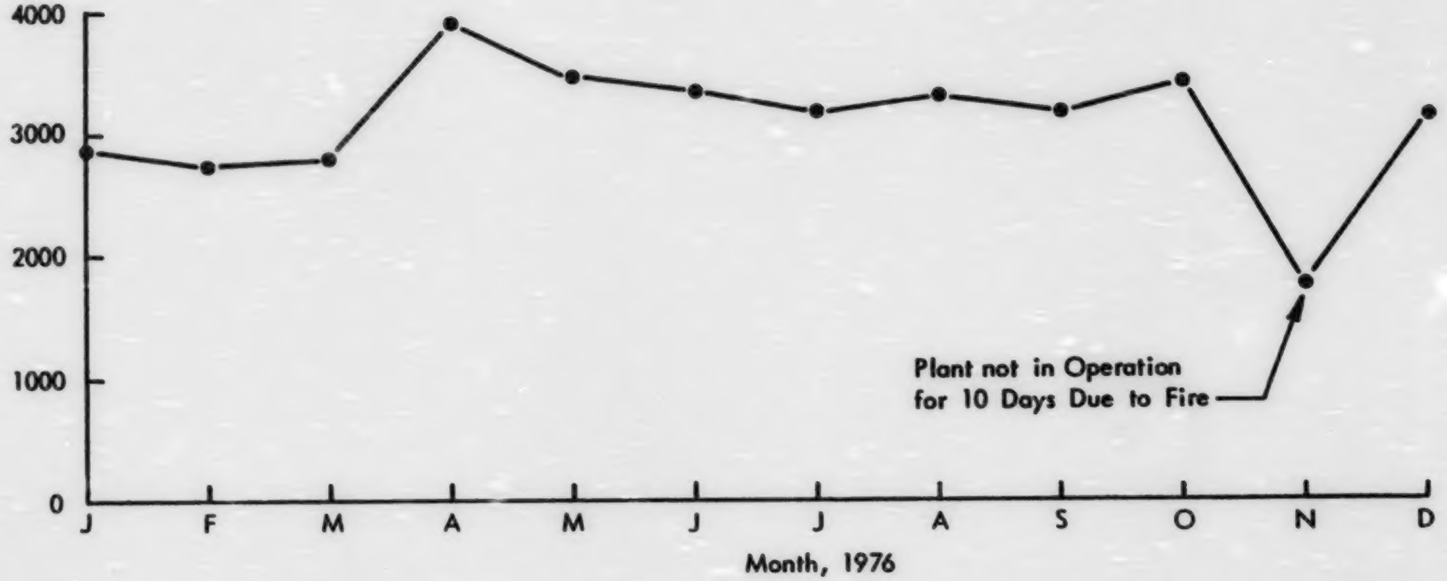

Figure 12. Monthly amount of raw refuse received.

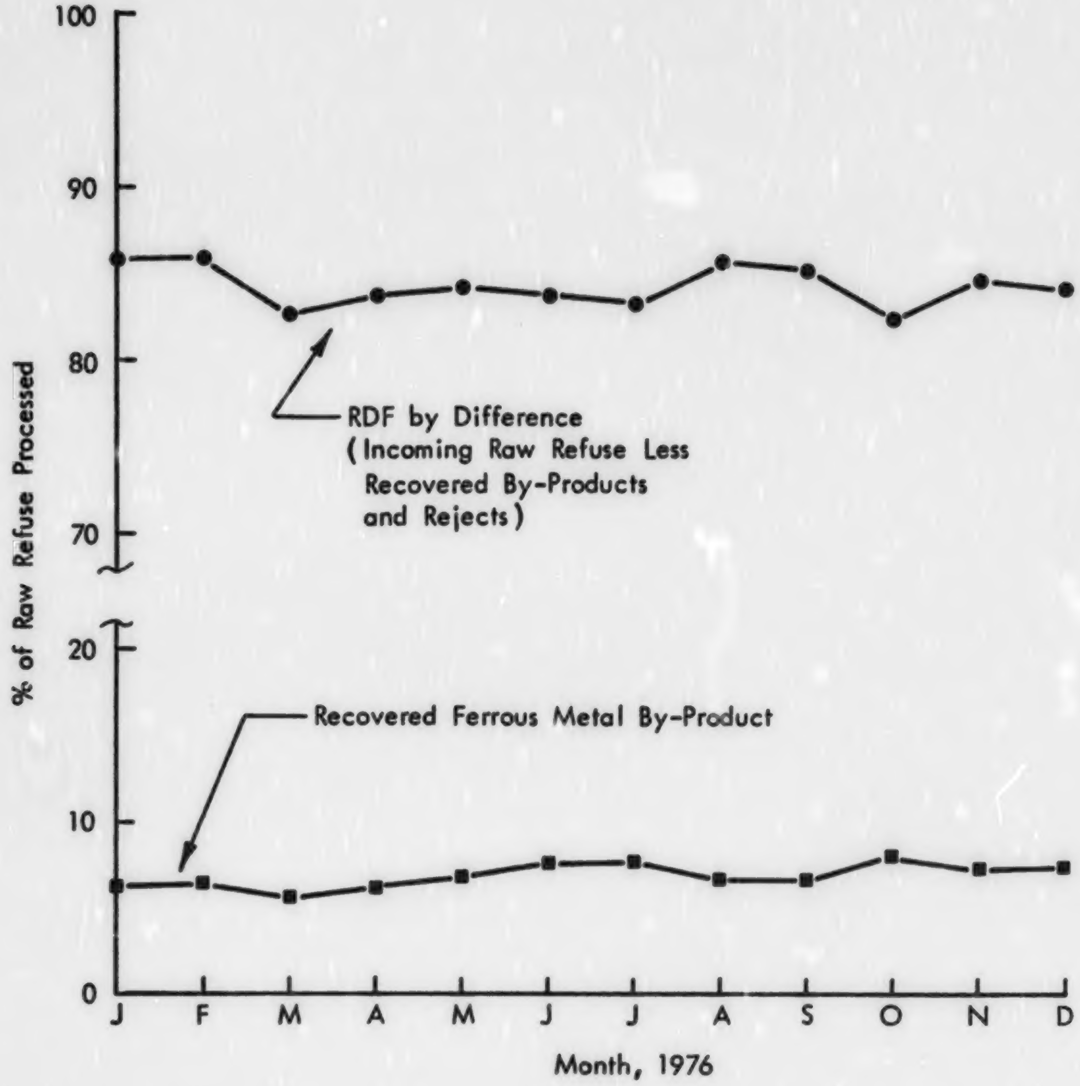

Figure 13. RDF and Fe-metal as percent of raw refuse.

SECTION 5

CHARACTERIZATION OF RDF

RDF was characterized by two separate methods. The first method included daily samples of RDF taken by the City of Ames on 286 different days throughout the year 1976, and analyzed for moisture and heating value. The second method included 14 days of samples analyzed for bulk density, screen size, proximate and ultimate analysis, ash chemical analysis and ash fusion temperature. Results from these samples show the range of RDF moisture and heating value over the whole year along with a very detailed analysis of RDF for a few days during the year.

MOISTURE AND HEATING VALUE OF DAILY SAMPLES OF RDF TAKEN BY THE CITY OF AMES DURING THE YEAR 1976

Daily values of moisture and heating value of RDF for 286 days from January 2 through December 31, 1976, are contained in Appendix Table B-1. These samples were taken by the City of Ames to determine heating value of RDF so that proper credit could be given the refuse processing plant for the fuel it produces. The City of Ames has made this information available to show the daily variability of RDF.

Sampling Procedure

Daily samples were taken from the discharge of the storage bin as RDF was being fed to the boilers. The storage bin bottom is fitted with drag conveyors which discharge into a chute leading to the pneumatic conveying system which delivers RDF to the boilers. Once per day, between 7 and 9 a.m., a 1 liter (1 qt) sample of RDF was manually taken from the top of a selected drag conveyor using a 1 liter scoop. This 1 liter sample was placed in a plastic bag, sealed airtight and sent to the laboratory for analysis. As shown in Appendix Table B-1 samples were taken generally every workday, with exceptions for some weekend days, holidays, etc.

Results

Table B-1 in the Appendix shows the date the sample was taken. However, because the samples are the discharge from the storage bin they cannot be correlated to any specific day of the week. The storage bin has a storage capacity of 456 Mg (500 tons) of RDF. Plant production of RDF is approximately 120 Mg/day. Normal operation is for continuous burning of RDF in the boilers so that RDF consumed during a week matches the RDF produced for the week. However, for any particular day the RDF being discharged from the storage bin could be RDF produced that day or a previous day, or a mixture of RDF from two or more days of plant production.

Appendix Table B-1 shows the normal daily variation in RDF moisture and heating value. Figure 14 is a graphical presentation of daily moisture and heating value over the total 1 year period. Moisture free heating value is plotted versus days because as received heating value is obviously affected by moisture content. An analysis of Figure 14 reveals that daily values of moisture and heating value vary considerably and this variability appears to be random. A statistical test of correlation between moisture and day of the year, and heating value and day of the year was conducted. The results of this indicate no significant statistical correlation between daily values and day of the year.

However, when the monthly average values are compared, there are some seasonal trends present. Statistical analysis of variance tests revealed significant differences between some of the monthly average values. Figure 15 presents the monthly mean values. During 1976, moisture free heating value was lower in the spring and summer months. November had the highest mean value. However, the November data include only 13 days of samples because of plant unavailability due to a fire.

Variation of RDF moisture content by month is not as pronounced as is the heating value variability. Moisture content was highest during the spring months which is what would be expected due to spring yard cleanup, etc. However, all the reasons for seasonal trends, if present, are not known from the study thus far. The composition study of RDF planned to be conducted during 1977 may present information allowing a greater understanding of the reasons for the seasonal trends.

For a 1-year period extending from September 1974 through September 1975, the St. Louis Refuse Processing Plant was evaluated.1/ This evaluation

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1/ Fiscus, D. E., P. G. Gorman, M. P. Schrag, L. J. Shannon. St. Louis Demonstration Final Report: Refuse Processing Plant Equipment, Facilities, and Environmental Evaluations. Prepared for U.S. Environmental Protection Agency by Midwest Research Institute, Kansas City, Missouri, April 15, 1977.

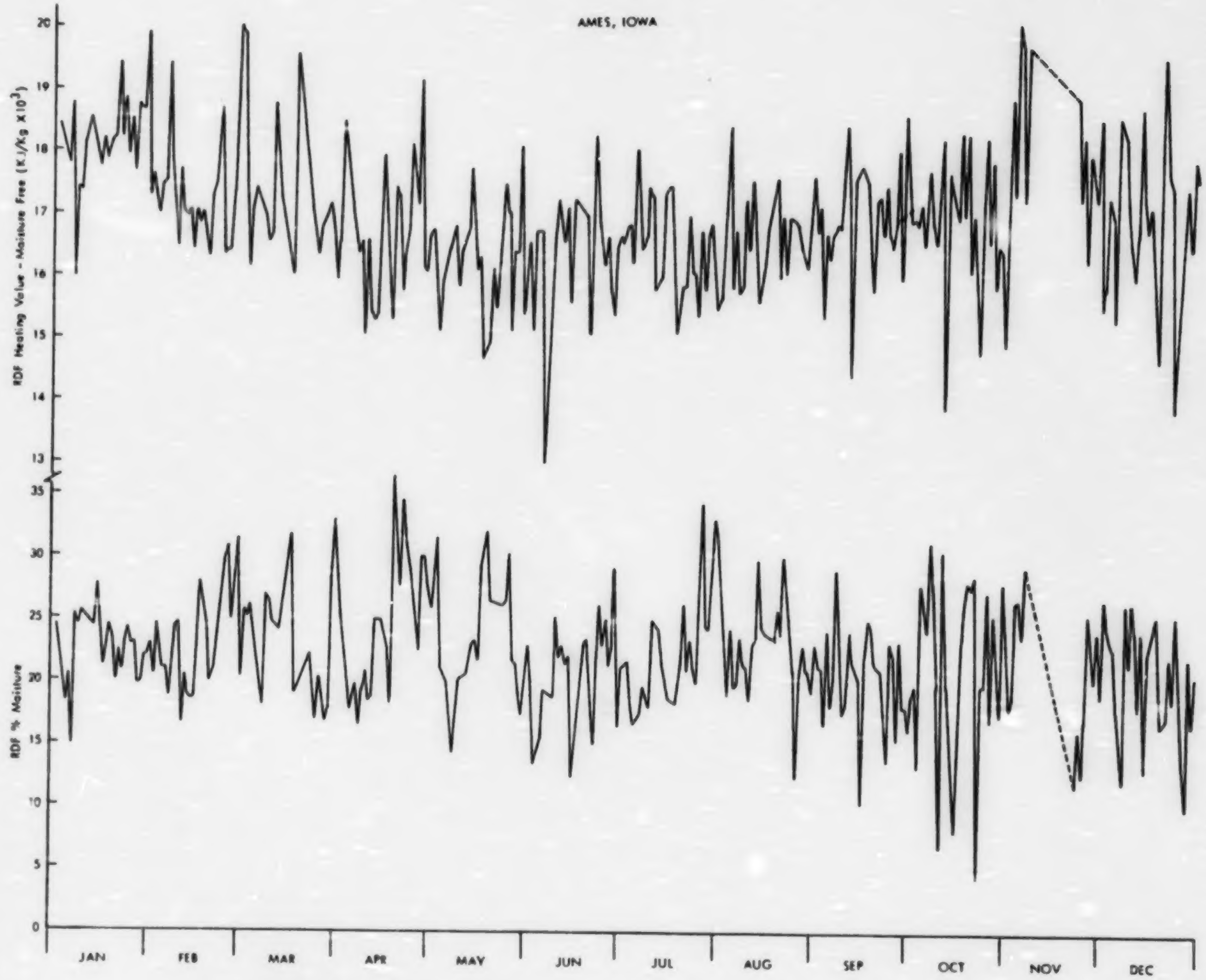


Figure 14. Daily values of RDF moisture and heating value.

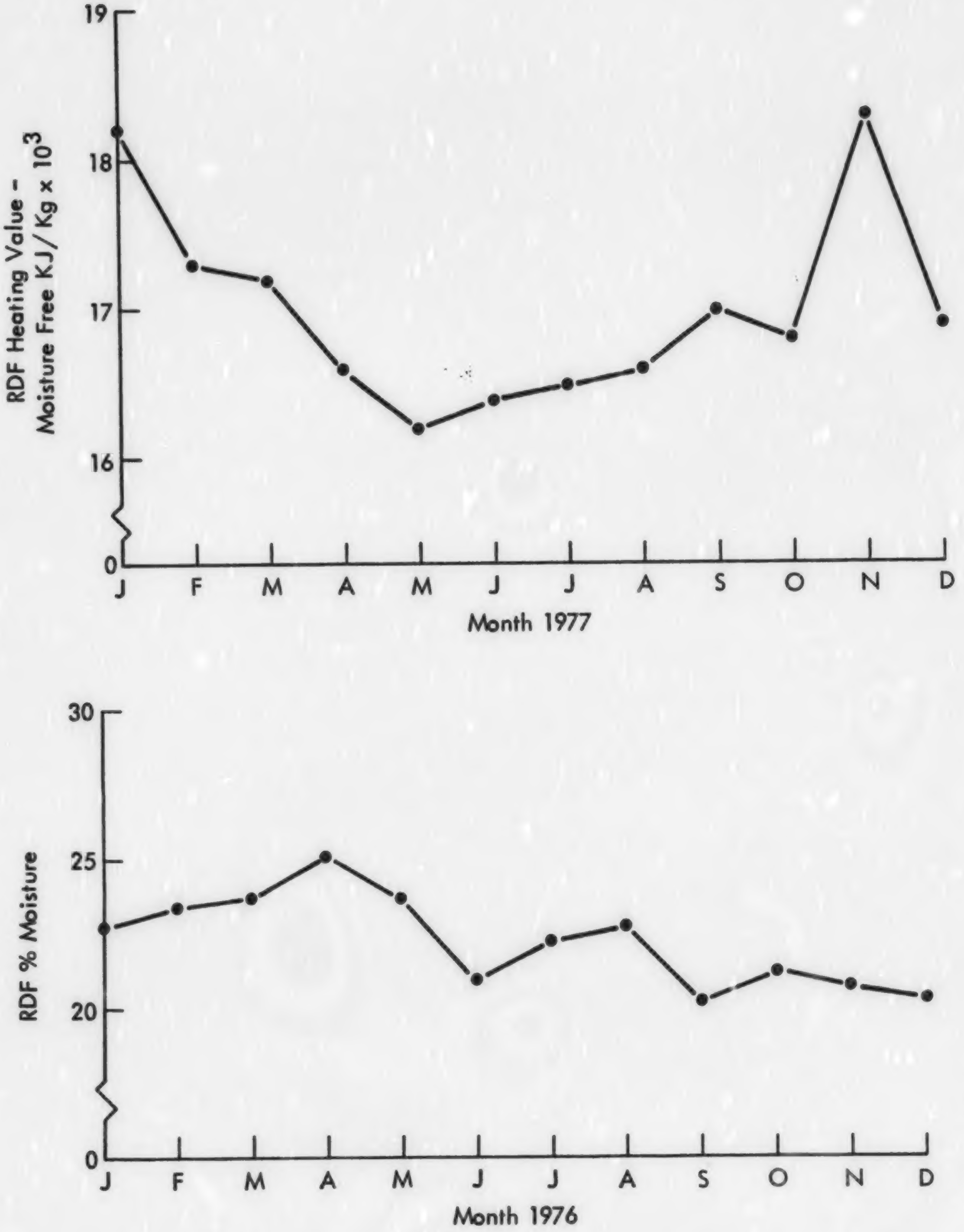


Figure 15. Monthly average value of RDF moisture and heating value.

included daily samples of RDF analyzed for heating value and moisture. Therefore, a comparison can be made between the RDF produced for 1 year at St. Louis and the RDF produced for 1 year at Ames. This comparison is shown in Table 7. These results represent 28,053 Mg of municipal solid waste processed at St. Louis during the 12-month period and 37,137 Mg processed during 12 months at Ames. Since daily samples of RDF discharged from the storage bin at St. Louis were taken for only 10 days, the only year long period that can be compared to Ames are daily values of RDF entering the storage bin at St. Louis. A statistical analysis of the St. Louis data showed that there was no significant difference between RDF entering or being discharged from the storage bin. Therefore, comparison of RDF entering the storage bin at St. Louis versus RDF leaving the storage bin at Ames is valid. Mean values were compared utilizing the test of statistical difference between independent samples. All three means were significantly different.

RDF BULK DENSITY, PROXIMATE AND ULTIMATE ANALYSIS, SCREEN SIZE, AND ASH CHEMICAL ANALYSIS AND FUSION TEMPERATURE

Values of moisture and heating value of RDF for a full year on the basis of samples taken by the City of Ames were presented in the preceding section (4). To provide a more complete characterization of RDF, 14 daily samples of RDF discharged from the storage bin were taken by personnel of the Iowa State Engineering Research Institute during the period March 17 through June 14, 1977. Samples were analyzed for bulk density, proximate and ultimate analysis and ash analysis. Samples from nine of these 14 days were sized, using a laboratory sieve machine. This was done to check out the sizing procedure and laboratory equipment.

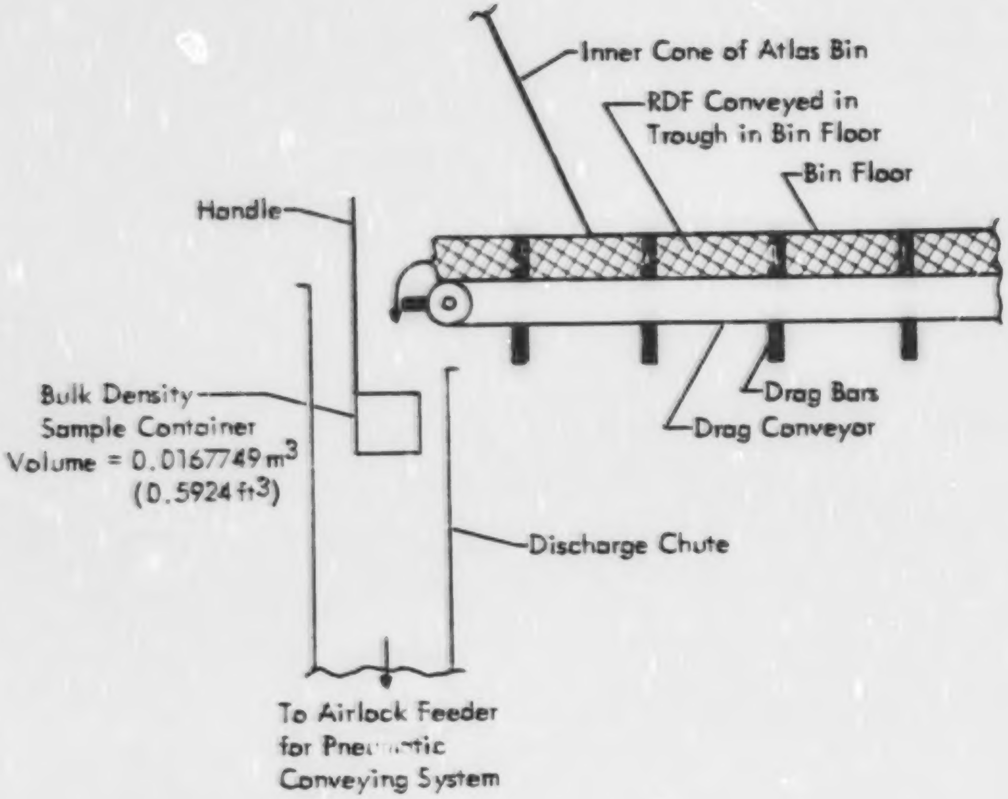
Sampling Procedure

Figure 16 shows the procedure used for sampling and determination of bulk density. Once per hour, the 16.8 liter sampling container is placed in the discharge chute below the drag conveyor discharge. The container is allowed to fill with RDF and then is removed from the discharge chute. The container is leveled off and the amount of RDF in the container weighed. After the weight is determined, a portion of this collected RDF is placed in a separate container to form a daily composite sample. The storage bin has four drag conveyors. If more than one conveyor is in use, the above procedure is repeated for each conveyor being used.

A minimum of four samples per day were taken. The bulk density reported each day is the total weight of RDF collected divided by the total volume collected:

TABLE 7. COMPARISON OF DAILY SAMPLES OF RDF TAKEN OVER 1 YEAR PERIOD, ST. LOUIS - SEPTEMBER 1974 THROUGH SEPTEMBER 1975, AMES - JANUARY THROUGH DECEMBER 1976

Characteristic	Moisture %		Heating value (kJ/kg)			
			As received		Moisture free	
	St. Louis	Ames	St. Louis	Ames	St. Louis	Ames
Mean $\overline{X}$	26.55	22.23	10,636	13,188	14,494	16,967
Maximum value	42.2	36.38	13,613	16,970	16,816	20,239
Minimum value	2.3	4.31	6,932	9,678	10,503	13,023
Number of samples, n	97	286	97	268	97	268
Standard deviation, Sx	7.275	4,864	1,370.3	1,297.2	1,400.5	1,141.0


Inner Cone of Atlas Bin
RDF Conveyed in Trough in Bin Floor
Bin Floor
Handle
Bulk Density Sample Container Volume = 0.0167749 m3 (0.5924 ft3)
Drag Bars
Drag Conveyor
Discharge Chute
To Airlock Feeder for Pneumatic Conveying System

PROCEDURE

Sample container placed below drag conveyor discharge, container filled and then removed from discharge chute. Container then leveled off and weight determined.

Two or more conveyors normally used for conveying refuse. Above procedure repeated for each conveyor in use. Bulk density reported is total weight of RDF collected divided by total volume.

$$\text{Bulk Density} = \frac{\Sigma \text{ sample container weight}}{(\text{Number of samples})\ (0.0167749 \text{ m}^3)}$$

Figure 16. Procedure for determination of bulk density.

$$\text{Bulk density} = \frac{\Sigma \text{ sample container weight}}{(\text{Number of samples})\ (0.0167749\ m^3)} = kg/m^3$$

This procedure is different from that used by the City of Ames as described previously. The primary difference is that the RDF is sampled in a free fall condition while the City of Ames samples were taken from the top of a conveyor. Also, the laboratory analysis sample is the composite of a minimum of four individual daily samples taken 1 hr apart. This procedure is unlike the daily sampling of RDF by the City of Ames, which used only one daily sample for analysis.

Laboratory Results

Table 8 shows the sampling schedule and the identification of each sample number as to the date and day of the week it was taken. The data in Tables 9 through 12 use only the sample number for identification.

Table 9 presents the values of bulk density and proximate and ultimate analysis. The screen size distribution is reported in detail in Table 10. To make comparisons easier, the geometric mean diameter and the geometric standard deviation were calculated. This method assumes a straight line logarithmic distribution of particle size. The geometric mean diameter is the size at which half the particles are larger than the mean and half are smaller. The geometric standard deviation is the dispersion about the mean. A value close to 1 indicates a small dispersion, while a large value indicates that particles are widely distributed over a large size range.

In early March 1976, the second stage shredder was taken out of service due to a bearing failure and was not placed back in service until March 28, 1976. Therefore, Samples Nos. 1 and 2 are single shredded RDF. The major effect of single versus double shredding is on particle size. Therefore, the particle size mean values were calculated only for the double shredded RDF.

Table 11 shows the chemical analysis of RDF ash and Table 12 lists the fusion temperatures of RDF ash. The major constituent of RDF ash is silica (SiO_2), one of the important items used in determining the slagging characteristics of an ash. It is desirable to have low silica content. However, interpretation of these ash analyses results, as well as the ash fusion temperatures, can best be made after the same categories of data are available for the specific coals used at Ames.

TABLE 8. SAMPLING SCHEDULE RANDOM SAMPLING OF RDF AT STORAGE BIN DISCHARGE

Sample number	Day of week	Date (1976)
1	Wednesday	March 17[a]
2	Tuesday	March 23[a]
3	Friday	April 2
4	Wednesday	April 7
5	Thursday	April 15
6	Monday	April 19
7	Tuesday	April 27
8	Thursday	May 6
9	Wednesday	May 12
10	Thursday	May 20
11	Tuesday	May 25
12	Friday	June 4
13	Monday	June 7
14	Monday	June 14

[a] Single stage shredding due to second stage shredder out of service because of bearing failure. Second stage shredder back in service on March 28, 1976, and Tests 3 through 14 are double shredded refuse.

TABLE 9. BULK DENSITY, AND PROXIMATE AND ULTIMATE ANALYSIS OF RDF DISCHARGED FROM THE STORAGE BIN (As received, all percents by weight ASTM Method D271 for all values except bulk density)

Sample No. (test day)	Bulk density (kg/m^3)	Heating value (kJ/kg)	Moisture (%)	Ash (%)	Volatile matter (%)	Fixed carbon (%)	Carbon (%)	Hydrogen (%)	Oxygen (%)	Sulfur (%)	Chlorine (%)	Nitrogen (%)
1	134.7	13,328	22.00	11.12	57.54	9.34	32.58	4.91	28.32	0.46	0.25	0.36
2	97.0	12,406	19.38	17.44	58.21	4.97	32.27	4.36	25.40	0.60	0.26	0.29
3	152.2	11,475	29.24	21.38	48.56	0.82	28.36	4.21	15.84	0.23	0.20	0.54
4	104.4	13,812	18.65	15.24	59.21	6.90	33.59	4.61	27.14	0.29	0.16	0.32
5	129.5	13,120	19.71	17.99	56.69	5.61	32.41	4.88	24.02	0.33	0.17	0.49
6	157.0	12,084	31.77	19.39	46.57	2.27	27.98	4.64	14.92	0.64	0.25	0.41
7	127.8	11,875	28.32	15.61	52.48	3.59	29.41	4.98	19.94	0.88	0.22	0.64
8	122.5	13,948	20.97	13.74	57.22	8.07	33.90	5.08	25.21	0.60	0.14	0.36
9	156.0	15,219	19.92	19.48	55.55	5.05	32.66	4.96	21.99	0.44	0.21	0.34
10	137.6	13,099	25.61	13.55	54.56	6.38	31.33	4.68	24.00	0.30	0.20	0.33
11	122.4	11,909	25.10	22.52	51.12	1.26	26.57	4.20	20.51	0.27	0.26	0.57
12	116.1	13,413	20.82	18.25	56.16	4.77	30.23	5.08	24.56	0.29	0.32	0.45
13	125.5	13,914	20.92	18.77	54.99	5.32	31.03	4.95	23.38	0.36	0.19	0.40
14	113.8	13,104	20.05	18.76	56.32	4.87	29.72	5.18	25.10	0.26	0.59	0.34
Mean	128.3	13,050	23.03	17.37	54.65	4.94	30.86	4.77	22.88	0.43	0.24	0.42

TABLE 10. SIZE DISTRIBUTION OF RDF DISCHARGED FROM THE STORAGE BIN
(As received, all percents by weight)

	Size (mm) standard ASTM E-11 designation						Geometric	
Sample No. (test day)	% Larger than 63	% Smaller than 63	38.1	19.0	9.5	4.8	Mean diameter	Standard deviation
2[a/]	1.4	98.6	79.9	18.7	14.5	10.3	22.6	2.17
[b/]	3.2	96.8	85.2	65.5	38.2	22.2	12.4	2.56
8	0.8	99.3	88.5	67.7	40.4	22.5	11.7	2.46
9	1.2	98.8	93.9	81.5	58.1	35.1	8.4	2.36
10	0	100.0	91.1	75.8	58.0	28.6	9.2	2.42
11	1.1	98.9	93.2	71.0	48.6	26.5	10.2	2.42
12	3.3	96.7	89.0	73.3	50.9	23.3	10.5	2.47
13	3.8	96.2	84.3	66.2	41.5	24.5	12.0	2.64
14	0.1	99.9	95.1	68.9	38.4	25.3	11.1	2.35
Mean[c/]	1.7	98.4	88.9	65.4	43.2	24.3	12.0	2.42

a/ Single stage shredding due to second stage shredder out of service because of bearing failure. Second stage shredder not back in service until March 28, 1976.

b/ Extra sample taken April 22, 1976.

c/ Mean does not include single stage shredding data from March 23, 1976.

Note: First stage shredder grate size - 229 x 229 mm (9 x 9 in.).
Second stage shredder grate size - 76 x 127 mm (3 x 5 in.).

TABLE 11. LABORATORY ANALYSIS OF RDF ASH (Ash of RDF discharged from the storage bin ASTM Method D2795 (% by wt))

Sample No. (test day)	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O
1	42.54	11.90	3.91	1.42	1.12	14.75	2.49	4.83	1.70
2	41.82	13.53	2.99	1.76	0.99	15.48	2.26	3.68	1.52
3	49.95	10.20	8.13	1.11	0.66	11.60	3.19	3.46	2.16
4	46.80	13.30	3.69	1.41	0.52	12.90	2.55	3.88	1.64
5	50.20	11.70	3.93	1.68	0.70	12.90	2.19	3.90	1.57
6	51.60	11.60	3.76	1.67	0.28	11.80	2.18	4.60	1.73
7	44.25	10.40	3.65	1.20	0.78	15.30	1.95	3.73	1.54
8	54.10	8.45	4.46	1.07	0.36	11.90	2.46	5.08	1.65
9	54.00	11.30	4.45	1.35	0.96	10.45	2.13	4.19	1.87
10	43.22	18.17	3.46	1.30	0.88	10.40	2.04	4.07	2.26
11	51.41	9.39	2.91	1.28	0.73	13.72	2.57	5.22	1.67
12	49.18	11.61	4.28	1.47	1.25	12.14	2.63	4.86	2.10
13	48.27	11.73	4.57	1.55	0.99	12.52	2.37	4.59	2.04
14	47.32	11.20	5.90	1.96	0.85	12.02	2.30	5.13	1.75
Mean	48.19	11.75	4.29	1.45	0.79	12.71	2.38	4.37	1.80

TABLE 12. FUSION TEMPERATURE OF RDF ASH (Ash of RDF discharge from Atlas bin)

Sample No. (test day)	Temperature (°C)							
	Reducing atmosphere				Oxidizing atmosphere			
	IT	ST	HT	FT	IT	ST	HT	FT
1	1110	1116	1121	1127	1121	1127	1132	1138
2	1121	1127	1132	1138	1132	1138	1143	1149
3	1127	1138	1143	1149	1149	1154	1160	1166
4	1132	1143	1154	1160	1143	1154	1166	1171
5	1127	1138	1149	1160	1138	1149	1160	1171
6	1127	1132	1138	1143	1138	1143	1149	1154
7	1127	1132	1138	1143	1138	1143	1149	1154
8	1154	1171	1199	1249	1171	1204	1238	1282
9	1149	1160	1171	1182	1166	1193	1210	1227
10	1038	1138	1176	1210	1149	1193	1216	1243
11	1032	1154	1176	1204	1166	1188	1210	1227
12	1038	1166	1188	1221	1182	1204	1227	1249
13	1121	1166	1182	1216	1188	1193	1221	1232
14	1082	1116	1149	1182	1104	1132	1149	1188
Mean	1106	1143	1158	1177	1149	1165	1181	1197

ASTM Method D-1857

Nomenclature

IT = Initial deformation temperature
ST = Softening temperature (H = W)
HT = Hemispherical temperature ($H = \frac{W}{2}$)
FT = Fluid temperature
H = Cone height
W = Cone width

Variability of Results

As expected there was considerable variation from day to day in the sample results. Table 13 is the range of data (maximum and minimum values) encountered, as well as the mean or average value and the standard deviation and confidence interval for the complete spectrums of constituents (i.e., bulk density, proximate analysis, etc.).

Also listed is the total number of samples in the mean and the standard deviation. The coefficient of variation was also calculated. Coefficient of variation (CV) is a measure of variability because it expresses the standard deviation as a percent of the mean. As the absolute value of one characteristic increases over that of a different characteristic, the standard deviation may also increase.

A larger standard deviation does not necessarily mean larger variability, and thus CV is a method of accommodating this restriction. The formula for CV is as follows:

$$\mathrm{CV}\ (\%) = \frac{S_x}{\overline{X}}\,(100)$$

where $\overline{X}$ = mean, and

S_x = standard deviation.

An analysis of Table 6 shows that the variability expressed as CV often becomes quite high when the mean values are very low, such as sulfur, chlorine, nitrogen, ash P_2O_5, and screen size larger than 63 mm.

In ranking analysis constituents on a basis of the least to the highest variability, the coefficient of variation is as follows:

RANKING - LOWEST TO HIGHEST VARIABILITY

RDF

- Volatile matter (smallest variability)
- Hydrogen
- Carbon
- Heating value
- Geometric mean particle diameter
- Bulk density
- Oxygen
- Ash
- Moisture
- Nitrogen
- Sulfur
- Chlorine
- Fixed carbon
- Particle size larger than 63 mm (highest variability)

RDF ash

- SiO_2 (smallest variability)
- CaO
- MgO
- K_2O
- Na_2O
- TiO_2
- Al_2O_3
- Fe_2O_3
- P_2O_5 (highest variability)

TABLE 13. VARIABILITY OF DAILY VALUES OF CHARACTERISTICS OF RDF DISCHARGED FROM STORAGE BIN (As received all percents by weight)

Item	Range		$\bar{X}$ Mean	n number of samples	Sx standard deviation	Variability about the mean [±] at 95% confidence coefficient	CV coefficient of variation (%)
	Maximum value	Minimum value					
Analysis of RDF							
Bulk density (kg/m^3)	157.0	97.0	128.3	14	18.14	10.5	14.1
Heating value (kJ/kg)	15,219	11,475	13,050	14	1021.6	589.8	7.83
Moisture (%)	31.77	18.65	23.03	14	4.212	2.43	18.29
Ash (%)	22.52	11.12	17.37	14	3.170	1.83	18.25
Volatile matter (%)	59.21	46.57	54.65	14	3.702	2.14	6.77
Fixed carbon (%)	9.34	0.82	4.95	14	2.405	1.39	48.64
Carbon (%)	33.90	26.57	30.86	14	2.224	1.28	7.21
Hydrogen (%)	5.18	4.20	4.77	14	0.324	0.19	6.79
Oxygen (%)	28.32	14.92	22.88	14	3.903	2.25	17.06
Sulfur (%)	0.88	0.23	0.43	14	0.190	0.11	44.77
Chlorine (%)	0.59	0.14	0.24	14	0.110	0.06	45.12
Nitrogen (%)	0.64	0.29	0.42	14	0.106	0.06	25.44
Particle size							
Geometric mean diameter mm[a]	12.4	8.4	12.0	8	1.392	1.2	13.02
Percent larger than 63 mm	3.8	0	1.7	9	1.421	1.1	85.85
Analysis of RDF ash							
S_iO_2 (%)	54.10	41.82	48.19	14	4.059	2.34	8.42
Al_2O_3 (%)	18.17	8.45	11.75	14	2.288	1.32	19.47
Fe_2O_3 (%)	8.13	2.91	4.29	14	1.332	7.69	31.04
T_iO_2 (%)	1.96	1.07	1.45	14	0.256	0.15	17.74
P_2O_5 (%)	1.25	0.28	0.79	14	0.276	0.16	34.86
CaO (%)	15.48	10.40	12.71	14	1.608	0.93	12.66
MgO (%)	3.19	1.95	2.38	14	0.312	0.18	13.10
Na_2O (%)	5.22	3.46	4.37	14	0.598	0.35	13.68
K_2O (%)	2.26	1.52	1.80	14	0.244	0.14	13.56
Fusion temperature of RDF ash -°C							
Reducing atmosphere							
Initial deformation (IT)	1154	1032	1106	14	41.47	72	3.75
Softening (ST) (ST)	1171	1116	1163	14	18.15	31	1.59
Hemispherical (HT)	1199	1121	1158	14	23.57	41	2.04
Fluid (FT)	1249	1127	1177	14	37.42	65	3.18
Oxidizing atmosphere							
Initial deformation (IT)	1188	1104	1149	14	23.48	41	2.04
Softening (ST)	1204	1127	1165	14	28.62	50	2.46
Hemispherical (HT)	1238	1132	1181	14	37.10	64	3.14
Fluid (FT)	1282	1138	1197	14	45.53	79	3.80

[a] Particle size does not include high value on March 23, 1976, due to single stage shredding.

Comparison to Daily Samples Taken by the City of Ames

Various comparisons can be made of these 14 daily samples to the City of Ames daily results of RDF moisture and heating value discussed in the preceding section.

A statistical treatment of the data compared the mean value of the 14 daily samples to the mean value of 286 daily samples taken by the City of Ames for the year 1976. There was no statistically significant difference at the 95% confidence level in these mean values of moisture and heating value as shown below:

	Moisture (%) by weight		As-received heating value (kJ/kg)	
	Mean value	Standard deviation	Mean value	Standard deviation
14 Daily samples	23.03	4.212	13,050	1,021.6
286 Daily samples over year 1976	22.23	4.864	13,188	1,297.2
% Difference (14 samples versus 286 samples)	3.6		1.1	

Comparison of Ames and St. Louis RDF

The preceding section discussed the RDF heating value and moisture content data determined for RDF at St. Louis. Bulk density, proximate and ultimate analysis and screen size were also determined for RDF produced at St. Louis. A comparison of all of these values between St. Louis RDF and the 14 daily samples of Ames RDF was made.

Table 14 shows one of the very important conclusions of the statistical analysis of the data. The Statistical F Test was employed to compare the variability of RDF between Ames and St. Louis. The results are shown in Table 8. There is no statistically significant difference in variability about the mean except for percent sulfur. This is an important conclusion which could affect future material sampling programs at refuse processing plants. Ninety-seven daily samples of RDF produced at St. Louis were analyzed for proximate and ultimate analysis, screen, size, metals by chemical analysis, and composition by visual means, and 10 samples were analyzed for bulk density. Therefore, the daily variability is well known. This variability apparently does not differ between these two plants, at least for the comparisons that could be

TABLE 14. TEST OF SIGNIFICANT DIFFERENCE IN VARIABILITY BETWEEN DAILY SAMPLES OF RDF PRODUCED AT AMES AND ST. LOUIS

Item Analysis of RDF	n Number of samples Ames	 St. Louis	Sx Standard deviation Ames	 St. Louis	Variance ratio F (Sx_1^2/Sx_2^2)	Significant difference in sample variability[a]
Bulk density (kg/m^3)	14	10	18.14	12.9	1.98	No
Heating value (kJ/kg)	14	97	1,021.6	1,370.3	1.80	No
Moisture (%)	14	97	4.21	7.28	3.00	No
Ash (%)	14	97	3.17	4.61	2.11	No
Volatile matter (%)	14	97	3.70	5.07	1.88	No
Fixed carbon (%)	14	97	2.41	4.13	2.94	No
Carbon (%)	14	97	2.22	2.75	1.53	No
Hydrogen (%)	14	97	0.32	0.46	2.07	No
Oxygen (%)	14	97	3.90	3.68	1.12	No
Sulfur (%)	14	97	0.19	0.06	10.03	Yes
Nitrogen (%)	14	97	0.11	0.08	1.89	No
Particle size						
Geometric mean diameter (mm)	8	97	1.39	1.87	1.81	No

[a] Snedecor, G. W., and W. G. Cochran, Statistical Methods, 6th edition, Iowa State University Press, Ames, Iowa.

F at 99% = 3.27 for $n_1 = 97$, $n_2 = 14$ ($99\% = 1 - \alpha$)
F at 99% = 5.75 for $n_1 = 97$, $n_2 = 8$
No significant difference if $F \leq F_{0.01}$

made, including bulk density, proximate and ultimate analysis, and mean particle size.

The variability in sulfur content was lower at St. Louis than at Ames but the reasons for this lower variability are at present unknown.

A comparison of mean values between Ames and St. Louis is presented in Table 15. A statistical analysis was next used to determine if any difference between means exists. Since there was no significant difference in variability, a pooled standard deviation was calculated and the difference between means examined using the t-distribution for all items except sulfur. Because there was a significant difference in variability between Ames and St. Louis for sulfur, the standard t test could not be used. For sulfur, the treatment developed by Welch as reported by Brownlee[1] was used to test for a significant difference between means.

The statistical analyses of these comparisons showed that at the 95% confidence level, there was a statistically significant difference between Ames and St. Louis mean values of RDF characteristics except for bulk density and oxygen content, which had no statistically significant difference between means. The conclusions from this comparison are as follows:

Ames values higher than St. Louis	Ames values lower than St. Louis
Heating value	Moisture
Volatile matter	Ash
Carbon	Fixed carbon
Hydrogen	Nitrogen
Sulfur	
Geometric mean	
Diameter particle size	

The Ames RDF samples are of the discharge of the storage bin while the St. Louis RDF is that entering a storage bin, except for bulk density. Ninety-seven samples of RDF entering a storage bin were taken at St. Louis and analyzed for many items including bulk density. However, because of the compressibility or packing factor, RDF bulk density is higher leaving a storage bin. Therefore, bulk density of RDF leaving the storage bin at St. Louis was used for a valid comparison to the Ames RDF. Unfortunately, only 10 samples were taken of RDF leaving the St. Louis storage bin.

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[1] Brownlee, K. A. *Statistical Theory and Methodology in Science and Engineering*. John Wiley and Sons, New York, 1965.

TABLE 15. COMPARISON OF AMES AND ST. LOUIS MEAN VALUES OF DAILY SAMPLES OF RDF (Number of samples: St. Louis - 97 except 10 for bulk density; Ames - 14 except 8 for particle size.) (Results as received, all % by weight.)

Item Analysis of RDF	Mean values Ames	 St. Louis	% Difference (Ames versus St. Louis)
Bulk density (kg/m^3)	128.3	130.1	- 1.4
Heating value (kJ/kg)	13,050	10,636	+ 22.7
Moisture (%)	23.03	26.60	- 13.4
Ash (%)	17.37	21.70	- 20.0
Volatile matter (%)	54.65	43.60	+ 25.3
Fixed carbon (%)	4.94	8.10	- 39.0
Carbon (%)	30.86	26.00	+ 18.7
Hydrogen (%)	4.77	3.79	+ 25.9
Oxygen (%)	22.88	21.20	+ 7.9
Sulfur (%)	0.43	0.18	+138.9
Chlorine (%)	0.24	a/	a/
Nitrogen (%)	0.42	0.53	- 20.8
Particle size geometric mean diameter (mm)	10.7	7.4	+ 44.6

a/ Chlorine not determined during St. Louis tests.

There is an expected, but important, relationship of increasing heating value with decreasing moisture and ash content. Therefore, heating value of RDF was calculated on both a moisture free and a moisture and ash free basis.

The statistical standard deviation S_x and the coefficient of variation (CV) were calculated for the daily sample data to determine if variability of RDF heating value changes when expressed on a moisture free or moisture and ash free basis. Table 16 shows the results of these calculations. Variability as expressed by CV had only one definite trend. The CV for heating value was substantially less than for moisture and ash.

Figure 17 shows the relationship between heating balue and moisture content and ash content. There was a 71% correlation between heating value and moisture. There was not a good statistical percentage correlation between heating value and ash content due to the scatter in the data.

Figure 17 shows that the Ames RDF heating value is inherently higher than what was observed during the St. Louis tests. The boiler sees RDF heating value as is, with the moisture and ash content that is actually present. The higher as-received heating value at Ames is not entirely due to lower moisture and ash content. The heating value of the combustibles (moisture and ash free heating value) in the Ames RDF is also higher than the St. Louis RDF. The reasons for this may be answered when processing plant tests are conducted and an analysis for RDF or percent paper, plastic, etc., is conducted.

TABLE 16. MOISTURE FREE AND ASH FREE VALUES OF DAILY SAMPLES OF RDF DISCHARGED FROM THE STORAGE BIN (All percents by weight)

Sample No. (test day)	Moisture % as received	Ash %		Heating value (kJ/kg)		
		As received	Moisture free	As received	Moisture free	Moisture and ash free
1	22.00	11.12	14.26	13,328	17,087	19,929
2	19.38	17.44	21.63	12,406	15,388	19,635
3	29.24	21.38	30.21	11,475	16,217	23,237
4	18.65	15.24	18.73	13,812	16,978	20,891
5	19.71	17.99	22.41	13,120	16,341	21,061
6	31.77	19.39	28.42	12,084	17,711	24,743
7	28.32	15.61	21.78	11,875	16,567	21,180
8	20.97	13.74	17.39	13,948	17,649	21,364
9	19.92	19.48	24.33	15,219	19,005	25,116
10	25.61	13.55	18.21	13,099	17,609	21,530
11	25.10	22.52	30.07	11.909	15,900	22.737
12	20.82	18.25	23.05	13,413	16,940	22,014
13	20.92	18.77	23.74	13,914	17,595	23,072
14	20.05	18.76	23.46	13,104	16,390	21,414
n	14	14	14	14	14	14
$\bar{X}$	23.03	17.37	22.69	13,050	16,956	21,995
Sx	4.212	3.170	4.685	1,021.6	922.8	1,619.4
CV %	18.29	18.25	20.64	7.83	5.44	7.36

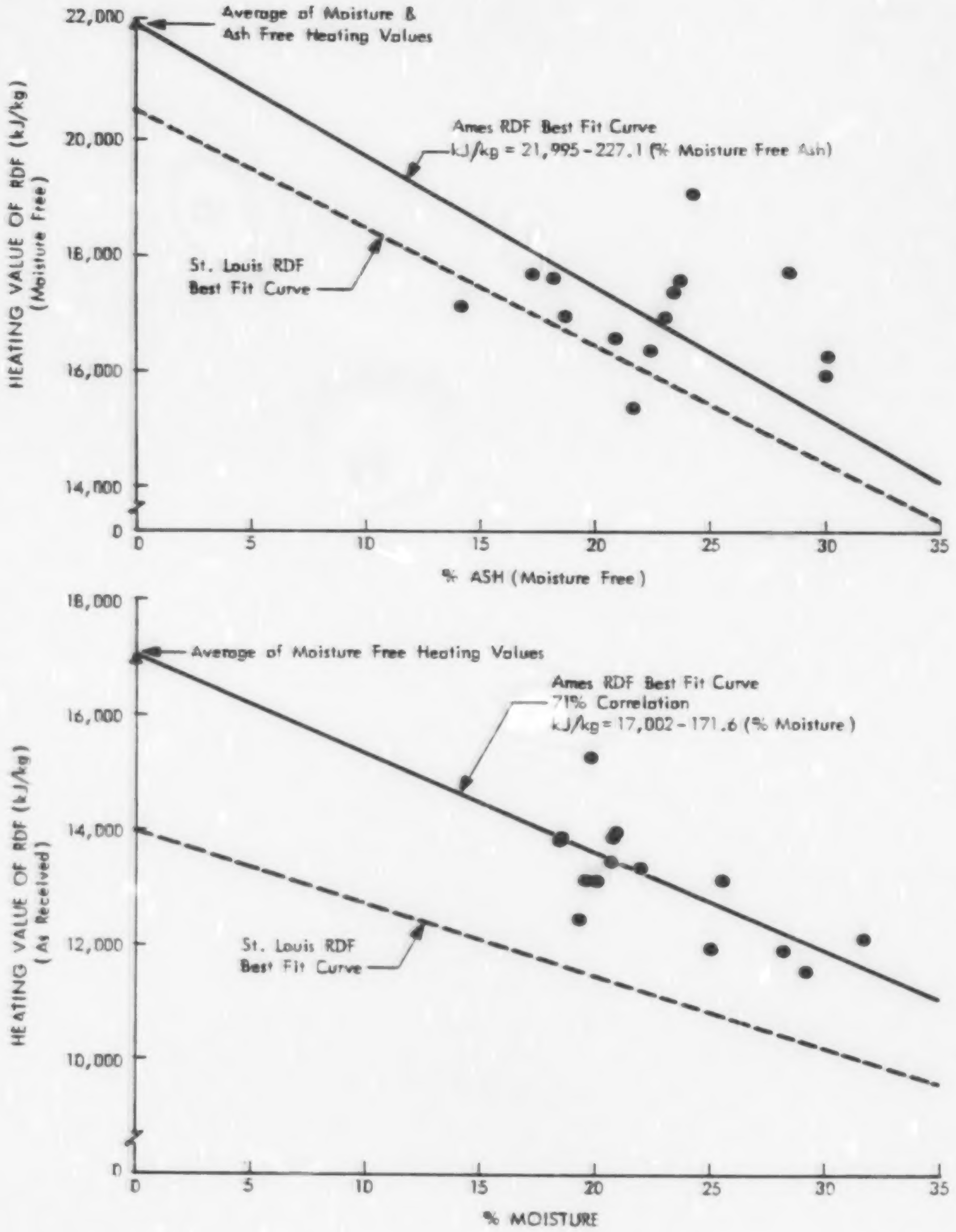

Figure 17. Heating value of refuse derived fuel (RDF) versus moisture and ash content for daily samples.

SECTION 6

REFUSE PROCESSING PLANT EQUIPMENT AND FACILITY EVALUATIONS

This section of the report provides an operating history of the Ames solid waste processing plant from a technical point of view, that is, as differentiated from an economic viewpoint. It is divided into eight parts as follows:

Plant start-up experience - A summary of plant operations. The actual daily log is included as Appendix Table C-1.

Refuse received - A summary of volumes, types and methods by which refuse is delivered to the processing plant. Refuse delivered by private vehicles is shown in Appendix Table C-2.

Plant labor - Operating history of the labor segment of the plant operation. A job description of the plant labor force is contained in Appendix Table C-3.

Processing hours - A summary of the operating hours and downtime of the plant and an assessment of plant utilization. Daily operating data are included as Appendix Table C-4.

Plant electric power consumption - A summary of electric power consumption for the processing plant. Weekly data are presented in Appendix Table C-5.

Refuse derived fuel (RDF) conveying and storage - This part of the report is separated from the rest of the material because it involves the subsystem which transports processed refuse from the plant to the Ames electric generating plant. The information presented here provides operating experience of this part of the operation.

Figure 18, supplied by Henningson, Durham and Richardson, Consulting Engineers, who designed the plant, shows a layout of the refuse processing plant to provide the reader with a conceptual idea of the various subsystems of the plant. Essentially, raw refuse first enters the plant system via infeed Conveyor C-1 into the first stage shredder, then, via Conveyor C-3

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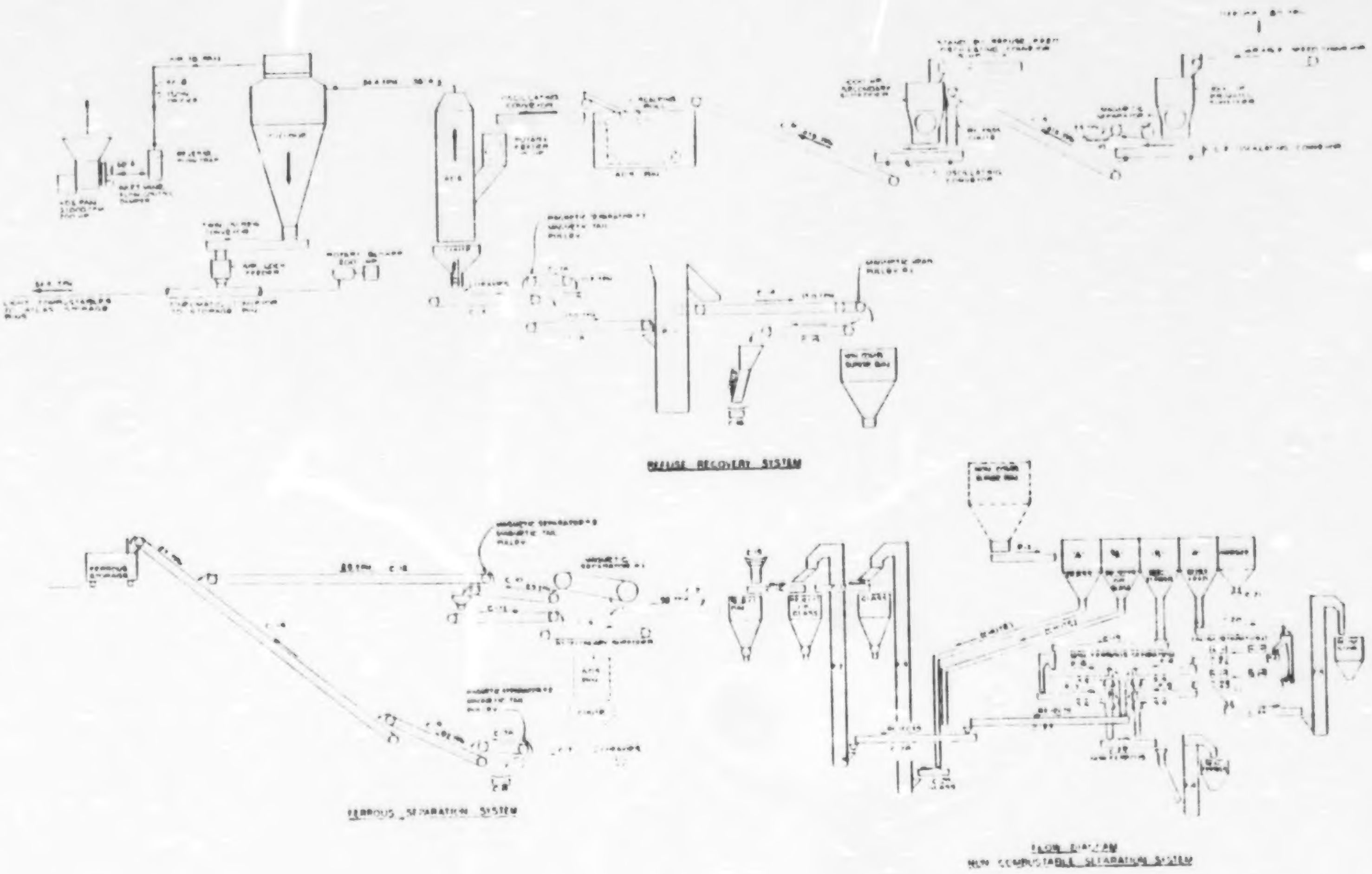
REFUSE RECOVERY SYSTEM
FERROUS SEPARATION SYSTEM
FLOW DIAGRAM
NON COMBUSTABLE SEPARATION SYSTEM

Figure 18. Refuse processing plant flow diagram, City of Ames, Iowa.

through the second stage shredder. A magnetic belt separator removes ferrous metal from the material flow-stream between the first and second stage shredder. Conveyor C-6 transports the material from the second stage shredder into the air density separation subsystem. Light material is transported via a pneumatic conveying system to a storage bin prior to transport to the electric power generating plant. The heavy material drops out of the air density separator onto conveying belts where it is transported through a series of magnetic pulley separators, a trommel screen and an electrical eddy current nonferrous metal separation system. In this process, the material is segregated into glass, aluminum metal, other nonferrous metal, ferrous metal and oversized material that is rerouted back through the system.

REFUSE PROCESSING PLANT ACTIVITY

This section contains a description of the major events which occurred at the refuse processing plant, including those prior to the actual beginning of this study (June 1, 1976), and extending through December 31, 1976. Even though the EPA grant investigations did not include the time prior to June 1, the start-up period for the processing plant may be important for other similar plants, since there is very little information available in the literature concerning refuse plant start-up experience. A review of the activities since the plant began operating (August 30, 1975) is a valuable addition to the literature. Since June 1, 1976, a daily activity log has been maintained; this is included as Appendix Table C-1.

The following discussion of operating experience at the Ames plant is presented in 11 categories. Typically, the plant has operated on one 8-hr shift per day, 5 days per week. A schedule of these operating hours is presented in Table 17. A work shift strictly for maintenenace and repair was instituted in September 1976 from 2 p.m. until 10:30 p.m., Monday through Friday. The work crew consists of four people. Consequently, the operating hours and one shift are not an exact description.

Shredder

On August 30, 1975, the first refuse was fed through the plant. Approximately 2 Mg was fed through the system at a very slow rate of only 9 Mg/hr (10 ton/hr). This procedure was to ensure that the various components of the system actually functioned. All equipment performed satisfactorily. Although minor spillage was noticed, it was not judged to be a major problem. Normal manual cleanup procedures could accommodate the spillage.

This successful first day's operation was then followed by the production amounts shown below for 4 months in 1975.

TABLE 17. PROCESSING PLANT DAILY OPERATING HOURS, JUNE - DECEMBER 1976
(Plant operating hours include the elapsed time between plant start-up and plant shutdown for the day.)

Day	Hours by month						
	June	July	August	September	October	November[a]	December
1	9.3	8.2	0	0	9.6	7.6	10.0
2	7.9	8.5	0.7	9.8	0	9.3	8.6
3	11.0	0	2.7	12.3	0	7.1	8.2
4	9.6	0	11.7	0	8.3	7.1	0
5	0	0	10.9	0	7.3	8.5	0
6	0	8.3	10.5	0	3.6	0	6.7
7	4.5	4.7	0	0	8.7	0	9.0
8	6.7	4.9	0	3.1	9.0	0	3.6
9	6.3	5.4	7.1	10.0	0	0	8.3
10	7.1	0	6.7	13.8	0	0	6.1
11	7.5	0	4.2	0	7.0	0	0
12	0	5.1	10.4	0	8.4	0	0
13	0	8.1	7.4	8.5	7.6	0	7.4
14	0	6.0	0	3.4	4.9	0	8.1
15	7.6	7.0	0	10.0	6.7	0	3.0
16	0	6.1	7.8	9.8	0	0	8.9
17	6.7	0	7.0	7.9	0	0	6.5
18	0	0	0	0	8.2	0	0
19	3.9	4.8	10.6	0	5.8	0	0
20	0	7.0	3.5	8.8	7.5	0	12.7
21	2.1	7.0	0	7.5	5.5	0	9.2
22	2.8	5.6	0	6.0	7.5	3.8	5.3
23	3.7	4.3	9.5	7.5	0	2.0	7.2
24	4.4	0	11.3	6.1	0	8.1	3.3
25	4.0	0	3.7	0	8.4	0	0

(continued)

TABLE 17. (continued)

Day	Hours by month						
	June	July	August	September	October	November[a]	December
26	0	7.0	6.5	0	4.8	7.4	0
27	0	8.5	5.5	7.0	4.8	0	5.6
28	8.7	3.4	0	5.5	7.1	0	7.5
29	6.4	5.7	0	2.8	1.3	6.6	6.2
30	5.0	8.0	8.5	1.4	0	9.5	6.0
31	-	0	11.2	-	0	-	5.7
Totals	125.2	133.6	157.4	148.2	142.0	77.0	163.1
Avg./day	6.3	6.4	7.5	7.8	6.8	7.7	7.1

[a] Does not include 10 days of cleanup and repair work resulting from November 6 fire damage.

Month (1975)	Raw refuse processed (Mg)	(tons)
August 30	1.8	(2)
September	513	(565)
October	1,529	(1,685)
November	1,712	(1,887)
December	2,647	(2,918)

During the first 5 months of operation the average maximum processing rate was only 23 to 32 Mg/hr of actual processing time (25 to 35 tons/hr). The desired and planned-for production rate is 45 Mg/hr (50 tons/hr).

The first stage shredder performed well. However, when a processing rate of 23 Mg/hr was exceeded, the second stage shredder experienced motor current surging, by which periodically a high amperage draw occurred for a few moments. Once during this period, the amperage was high enough for a long enough period of time that the motor overload circuit cut the electric power to the shredder motor. Thus, the second stage shredder was identified as a potential restriction to faster processing rates.

Shredder specifications during this 5-month period were as follows:

Shredder (stage)	No. of hammers	Weight of each hammer kg	(lb)	Grate size mm	(in.)
1	48	69	(152)	229 sq	(9 sq)
2	96	24	(52)	67 x 76	(2-5/8 x 3)

Because the first stage shredder worked well, the first conclusion was that the second stage shredder grate size was too small. Each grate opening was separated from the next grate opening by a 25.4 mm (1 in.) grate bar. In late January 1976, on one-fourth of the grates, every other bar was removed, resulting in 67 x 178 mm (2-5/8 x 7 in.) openings. This resulted in some improvement in shredder performance but not enough to reach the desired 42 Mg/hr.

Next, it was hypothesized that the shredder was volume limited. Due to the low bulk density of the refuse, it was thought there was not enough space inside the shredder to accommodate the desired volume of refuse. Therefore, early in February 1976, one-half of the hammers were removed. This also showed some improvement in shredder performance but again the desired processing rate was not achieved.

In February 1976, new grates purchased from the factory were installed. These grates were 76 x 127 mm (3 x 5 in.). These new grates plus using only 48 hammers instead of the original 96, increased the shredder rate to 45 Mg/hr (50 tons/hr) without excessive motor amperage surging. The effect on particle size is not known because no particle size measurements were made at this time.

Shredder specifications following this modification became:

Shredder (stage)	No. of hammers	Weight of each hammer		Grate size	
		kg	(lb)	mm	(in.)
1 (unchanged)	48	69	(152)	229 sq	(9 sq)
2	48	24	(52)	76 x 127	(3 x 5)

Because the system worked well, it was left as is, and the new grates were not operated with the original 96 hammers installed. Therefore, it is not known what the shredder performance would be with 96 hammers and 76 x 127 mm grates.

The plant personnel have found through experience that by allowing the hammers to wear down and increasing the clearance between the hammer and the grate, motor current surging is reduced. Secondly, it has been observed (although not verified by detailed tests) that the kilowatt hour per megagram of refuse processed is also reduced when the hammers are allowed to wear down. This situation is the opposite of the St. Louis experience where it was accepted that the hammers must constantly be retipped and hardfaced to build up the material worn away from the hammer face.

The Ames plant is not a research pilot plant, but a commercial facility. There was a desire by the city personnel to achieve good production rates. Therefore, once this goal was reached, there was no need to experiment further with the shredders. The result is that no information was recorded concerning the effect of hammer wear on RDF size and quality and plant operating costs. The only implication in this discussion is that increased clearance between the hammers and the grate resulted in a smoother operating shredder. The effects on other operations in the system such as metal separation and air classification are unknown.

Literature is available on shredding municipal solid waste.[1] However, the area of shredder internal volume, grate size, number of hammers, and refuse bulk density appears to be a desirable field of investigation for future work at Ames.

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[1] Ananth, K. P., and J. Shum. "Fine Shredding of Municipal Solid Waste." EPA-600/2-76-208, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711, July 1976.

Another problem on the second stage shredder was the fan effect (windage) caused by the hammers, which flow material out of the in-feed chute. This situation was improved by welding steel plates on the back side of the shredder throat, thereby reducing the clearance between the hammers and the shredder housing.

Information on shredder maintenance is presented in a later section entitled "Other Plant Evaluations."

Shredder Bearing Failure

The only major shredder maintenance item that has occurred to date was failure of one of the second stage shredder bearings in early March 1976. This was caused by breakage of the bearing oil sump sight glass. The broken sight glass resulted in rapid drainage of oil from the sump and subsequent bearing failure. The shredder was out of operation for 2-1/2 weeks because the bearing failure had scored the shaft. The shaft had to be built up and turned down before the new bearing could be installed. However, the refuse processing plant was out of service for only 2 days. Plant operations continued by placing some of the second stage shredder grates in the first stage shredder and operating the plant with one shredder. The plant did not perform well with single stage shredding, but it was able to continue operating. The single stage shredding described above resulted in approximately twice as large a mean particle size of RDF. The mean RDF particle diameter for the normal double stage shredding was 12.0 mm versus 22.6 mm for single stage shredding (Table 4 in preceding section). This large particle size tended to cause pluggage of the plant material hauling equipment.

Fire in the Shredders

At 3:15 p.m., on July 12, 1976, a fire occurred in the shredders. It is theorized that at least 19 liters (5 gal.) of gasoline in glass or easily breakable containers entered the first stage shredder undetected and a spark from the hammers striking metal in the refuse caused ignition.

In any event, what is known is that flames shot upward out of the first-stage shredder in-feed opening and set off the sprinklers and fire alarm in the raw refuse receiving area. Flames then traveled along the conveyor belt from the first stage shredder to the second stage shredder.

No damage was done other than shutting down the processing plant for the balance of the work day. The fire was considered dead by 5:30 p.m. The pad of the refuse on the rubber conveyor belt prevented it from being burned and no damage was done to the shredders.

Even though flames were present in the enclosed processing area, no dust explosion or flash fire occurred due to suspended particulates in the processing plant atmosphere. Processing commenced at 10:10 a.m., the next day, July 13, 1976.

In-Feed Conveyor for the First Stage Shredder

The raw refuse from the receiving floor is fed to the first stage shredder by a Z pan conveyor. The drop height from the in-feed conveyor to the shredder is approximately 1 m. Some material is thrown back out of the shredder feed opening, caught on the return section of the conveyor and dragged out of the shredder.

This problem was solved by building a metal chute termed a "dribble chute" to catch this material and route it to the vibrating pan receiving conveyor underneath the shredder.

A second problem that occurs is that long metal parts such as metal rods and shafts are sometimes thrown back out of the shredder in-feed opening. If these are caught in the hinge section of the Z pan conveyor, the conveyor becomes jammed. No solution has yet been found for this problem, and it remains one of the most frequent causes of downtime.

Vibrating Pan Conveyors

Generally, the plant personnel feel that all the vibrating conveyors are undersized for 45 Mg/hr (50 tons/hr).

The height of the discharge opening from the first stage shredder to the receiving vibrating conveyor was increased 76 mm (3 in.) to allow a thicker depth of shredded refuse on the conveyor to achieve 45 Mg/hr flow rate.

Air Density Separator (ADS)

Air Separation Chamber (See Figure 19)--

At first a zig-zag or Z-shaped adjustable throat chamber arrangement was tried, but this did not prove successful. The manufacturer adjusted the throat dimension, resulting in a straight-walled, wedge-shaped throat area.

There was still too much oversized or heavy material in the light fraction (RDF). It was determined that some material was not falling straight down out of the rotary airlock but was being thrown out with a horizontal component of velocity. This allowed some shredded refuse to be picked up by the upward moving airstream before the material could enter the adjustable throat separation chamber (see Figure 20).

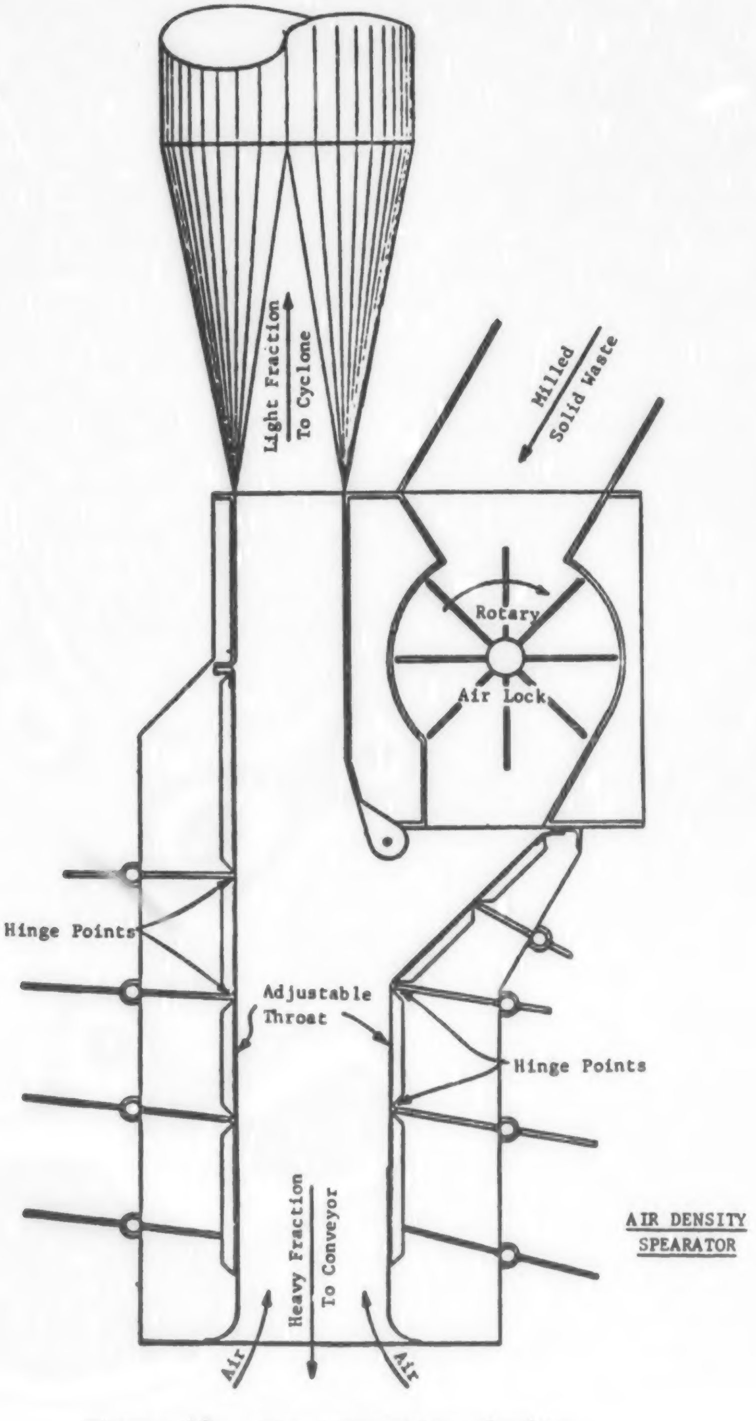
Light Fraction
To Cyclone
Milled
Solid Waste
Rotary
Air Lock
Hinge Points
Adjustable
Throat
Hinge Points
AIR DENSITY
SPEARATOR
Heavy Fraction
To Conveyor
Air
Air

Figure 19. Air separation chamber.

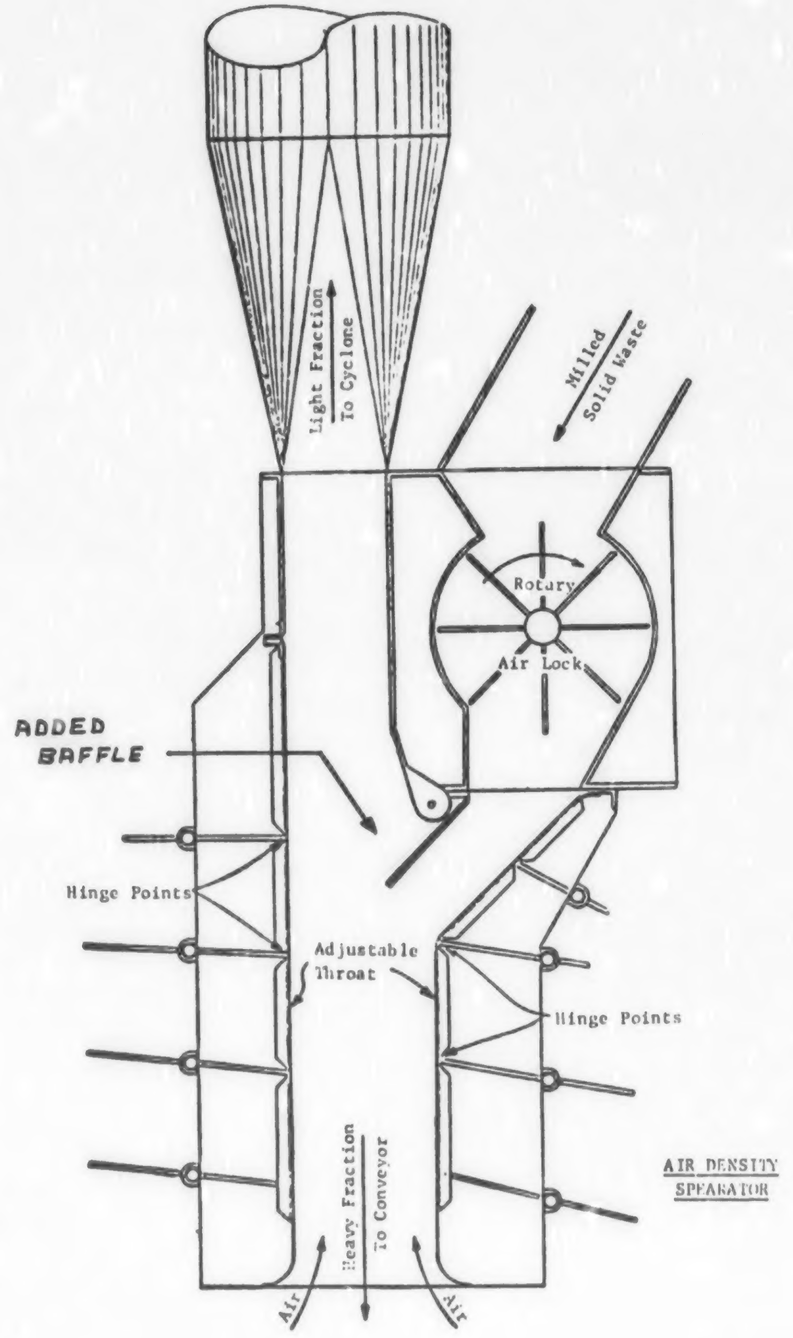
Light Fraction
To Cyclone
Milled
Solid Waste
Rotary
Air Lock
ADDED
BAFFLE
Hinge Points
Adjustable
Throat
Hinge Points
AIR DENSITY
SPEARATOR
Heavy Fraction
To Conveyor
Air
Air

Figure 20. Modification to air separation chamber.

The problem was solved by installing a 254-mm (10-in.) long baffle at the exit of the airlock (see Figure 20). This prevented any shredded refuse from being thrown with a horizontal component of direction, and ensured that all material fell downward before entering the air stream.

Air Flow Adjustment--

The ADS air flow is usually manually adjusted several times each week, especially in rainy weather. Dampness tends to affect the ADS performance, requiring air flow adjustment to maintain the same efficiency.

The ADS air flow is adjusted until small amounts of paper appear in the ADS heavies. This criterion is based on the theory that small amounts of paper in the heavies mean the minimum amount of noncombustibles are contained in the lights (RDF).

Metal Fatigue Failure--

Shredded refuse is fed to the ADS rotary airlock and air separation chamber by a vibrating pan feeder. Some vibration from this vibrating feeder is transmitted to the rest of the ADS equipment. Some metal plates failed due to metal fatigue and had to be reinforced.

Surge Bin Dust Emissions--

The ADS drag conveyor has a surge bin ahead of the drag conveyor to receive material from a belt conveyor leading from the second stage shredder (see Figure 21).

This surge bin was installed with the top open. Shredded refuse falling from the belt conveyor discharge to the bottom of the surge bin caused heavy dust emissions from the surge bin top. Fine dust particles were dislodged from the shredded refuse due to the impact of the refuse on the bottom of the surge bin and also the impact on the refuse already in the bin.

This problem was solved by covering the surge bin top with canvas.

Vibrating Feeder Pluggage--

The vibrating pan conveyor feeding shredded refuse to the ADS air separation chamber receives material from the ADS drag chain conveyor (see Figure 21).

Design capacity of the ADS system is 41 Mg/hr (45 tons/hr). Actual Mg/hr capacity of the vibrating feeder was not high enough, so that at high processing rates, material built up between the vibrating feeder and the drag conveyor discharge chute, plugging the drag conveyor. In early January 1976, this problem was solved by installing a sloping steel plate in the vibrating pan bottom (see Figure 22). This increased the effective slope of the conveyor and increased the throughput capacity of the conveyor.

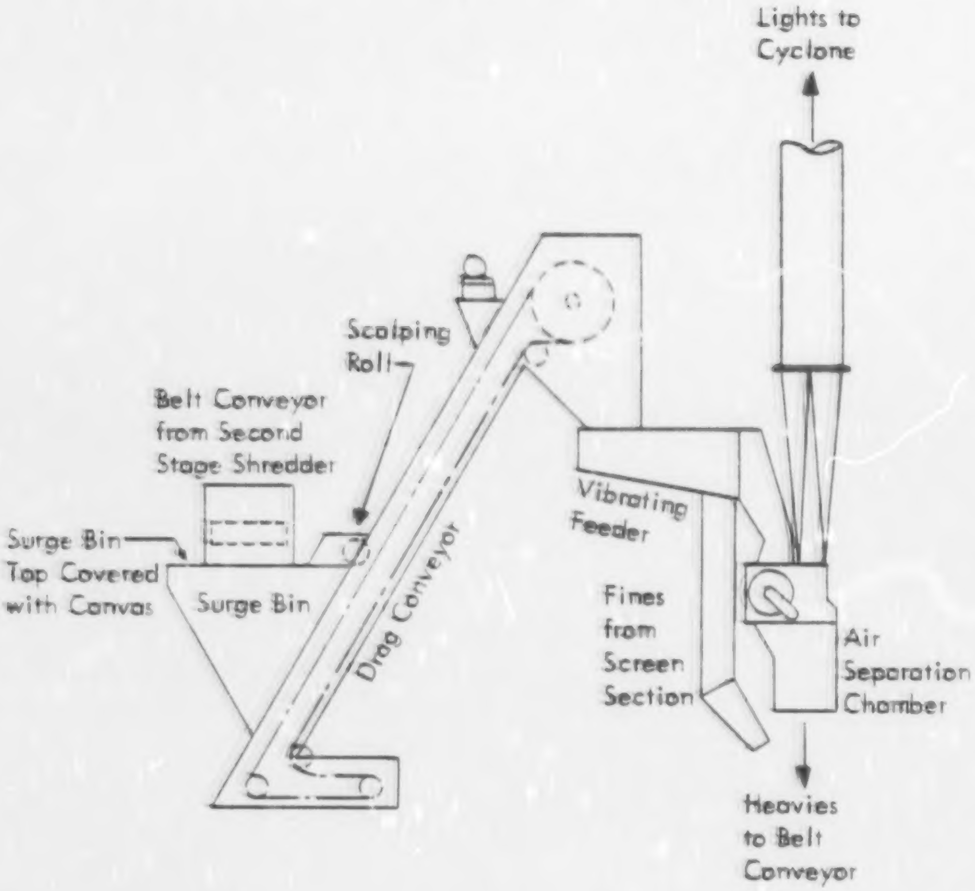
Lights to Cyclone
Scalping Roll
Belt Conveyor from Second Stage Shredder
Surge Bin Top Covered with Canvas
Surge Bin
Drag Conveyor
Vibrating Feeder
Fines from Screen Section
Air Separation Chamber
Heavies to Belt Conveyor

Figure 21. Air density separator.

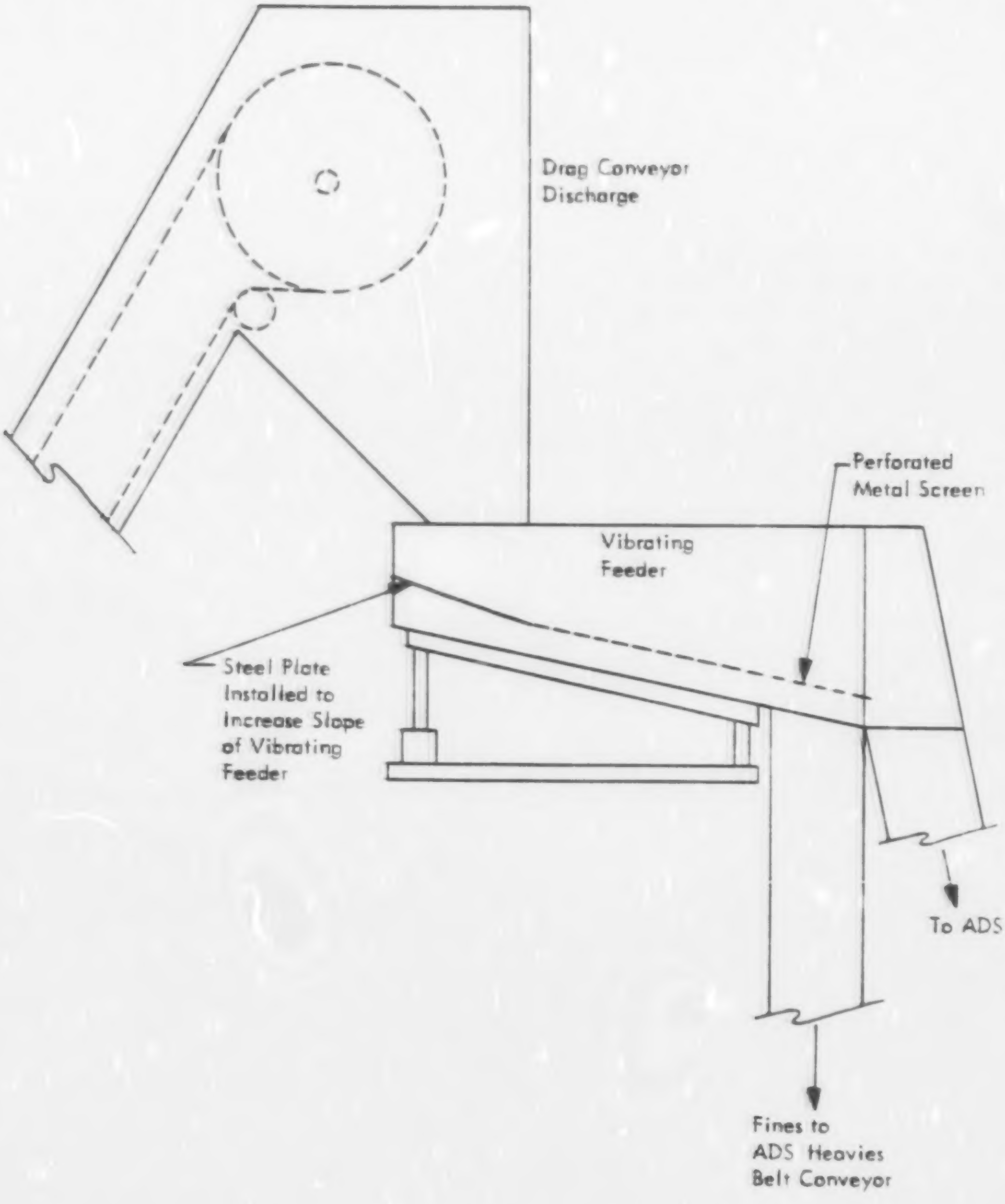
Drag Conveyor
Discharge
Perforated
Metal Screen
Vibrating
Feeder
Steel Plate
Installed to
Increase Slope
of Vibrating
Feeder
To ADS
Fines to
ADS Heavies
Belt Conveyor

Figure 22. Air density separator feeder modification.

Vibrating Feeder Screen Section Pluggage--

White goods such as stoves, refrigerators, etc., were normally stockpiled on the raw refuse receiving floor and shredded at the end of the work shift. The vibrating pan feeder has a perforated metal screen section to remove fine particles from the shredded refuse (see Figure 22).

When white goods were shredded, small metal particles not separated out by the magnetic belt separator would plug the perforated metal screen. This pluggage resulted in the bottom of the screen section of the pan having a rough, irregular surface instead of a smooth surface as in the case of unplugged holes. This rough surface caused shredded refuse to not slide along the vibrating pan. Instead, shredded refuse would build up on the pan and eventually plug the ADS drag conveyor discharge chute.

The solution to this problem was more frequent cleaning of the vibrating feeder screen. The screen is now cleaned every time after white goods are shredded. Also, some stockpiled white goods are being sold, nonshredded, to a metal scrap dealer, which reduces the percentage of white goods requiring shredding in the plant.

Drag Chain Conveyor Scalping Roll Pluggage--

The ADS drag conveyor has a scalping roll whose function is to level off and even out the volume of shredder refuse being pulled along by the drag chain. This is done to ensure a feed rate as even as possible to the ADS air separation chamber. The scalping roll is a round metal cylinder fitted with steel rods projecting outward. These rods act as fingers to dig into and level out any instantaneously large volume of refuse.

The problem is that long pieces of refuse such as rubber hose, nylon stockings, plastic tape, etc., can pass lengthwise through the shredder grates. Lengths in excess of 1 m often occur although their percentage in terms of weight of RDF is small. These long materials tend to wrap around the metal rods on the scalping roll, clogging up the roll, and making it ineffective.

Also, when clogged, the scalping roll motor becomes overloaded and the motor overload circuit will disconnect the electrical power to the motor.

The only solution to this problem found to date is frequent manual cleaning of the scalping roll. Cleaning must be done at least once per week.

Drag Chain Breakage--

Eight times between start-up and the end of July 1976, the flights on the drag chain have become bent and have broken loose from the chain on each side of the conveyor. This jams the conveyor. The plant must then be shut down, the drag conveyor cleaned out and new flights welded in place. The bottom return sprocket assembly and the chain take-up sprocket assembly were reversed in the original installation. This allowed shredded refuse to fall into the take-up assembly, causing jamming and eventual chain breakage. In early August 1976, the ADS system manufacturer installed new sprocket assemblies. Now, both the return and take-up sprockets have solid cylindrical drums instead of the previous open sprocket and shaft. These drums prevent refuse from falling through and clogging the take-up assembly. Plant personnel believe that this will alleviate drag chain breakage.

Cyclone Separator--

The separation efficiency of the ADS cyclone appears to be good based on visual observations. Only a very small amount of particulate matter is observed in the cyclone exhaust. The air intake filter for the pneumatic conveyor blower located adjacent to the cyclone exhaust has plugged only once since the start of operations. Pluggage was due to large pieces of plastic from plastic bags and wrapping material.

This cyclone exhaust is ducted back to the ADS air separation chamber inlet so that a recirculating air flow exists and no air emissions to the atmosphere occur. However, some dust from this recirculated cyclone exhaust is blown out into the processing plant basement.

Plans are to build an enclosed room around this cyclone exhaust and air separation air intake area, to prevent blowback into the rest of the processing area.

Ferrous Metal Separation

The ferrous metal recovery system has worked reasonably well from the first day of plant start-up. Although no sample data are presently available concerning overall efficiency of the system, the plant personnel believe that over 90% of the ferrous metal is picked up by the magnetic belt separator installed between the first and second stage shredders. The balance of the ferrous metal is then removed by the belt conveyor magnetic head pulley and two belt conveyor magnetic tail pulleys in the plant material handling system.

The only operational problem to date has been occasional clogging due to mattress springs.

Aluminum Separation

The processing plant commenced operation on August 30, 1975. However, installation of the aluminum separation system was not completed until January 1976. At first, there were a series of material handling problems. Some of the conveyor belts broke, and several vibrating pan conveyors and feed chutes had pluggage problems. Some of these conditions have been corrected. However, there remain problems of dissimilar metal corrosion, excessive cooling water usage because of lack of automatic cooling water flow controls, and material catching between Conveyors C-22 and C-23.

A major end product problem is that other nonferrous material such as copper, zinc, brass, etc., is also removed with the aluminum, resulting in a low purity aluminum scrap product. The aluminum separation system manufacturer and Alcoa are now working on this problem. Presently, consideration is being given to an air separation system to further purify the aluminum scrap. Flattened aluminum cans, for example, could be aerodynamically removed from the heavier particles of copper, zinc, and brass.

As of the end of December 1976, the problem of the aluminum scrap byproduct has not been solved. Aluminum separation is still considered to be in the start-up and shakedown mode.

Pneumatic Conveying Systems

Pneumatic Conveying from Processing Plant to Storage Bin--

This pneumatic line is 366 mm (14 in.) diameter in size and 213 m (700 ft) long, containing two 60-degree elbows.

In October and November 1975, this line was plugged three times due to very wet material entering the system. The pluggage could not be removed by the usual "Roto-Rooter" technique used for cleaning clogged sewers. Instead a "Sewer-Jet" was employed to clear the lines. A "Sewer-Jet" is a flexible hose line pushed through the pneumatic conveying line to the plugged section and water at approximately 4,100 kPa (600 psi) pressure ejected from the pipe tip.

This plugging problem has been solved by an operating procedure. Any masses of wet material are spread out and mixed with the other refuse on the raw refuse receiving floor by the front end loader operator. Therefore, the wet material is distributed with normal moisture content refuse before it is pushed onto the first stage shredder feed conveyor by the front end loader. This procedure requires alertness by the front end loader operator.

Another problem was uneven RDF distribution into the rotary airlock feeding RDF into the pneumatic conveying line. RDF is fed to the airlock by a screw conveyor which drops the RDF into one side of the airlock. RDF would then tend to build up on one side of the drop out portion. This condition was eliminated by changing the sheave size on the blower supplying the pneumatic conveying air on the basis of manufacturers' literature of blown air flow versus RPM. This increased air flow by approximately 10%, eliminating the uneven drop out problem. Although air velocities were not measured, the increased air flow was eventually at a high enough velocity to pick up and carry away the RDF, even though the distribution into the air stream from the airlock feeder was uneven.

Pneumatic Conveyor Line Elbows--

All the pneumatic lines, both from the refuse processing plant to the Atlas bin and from the Atlas bin to the boilers were installed with replaceable wear back liners in the elbows. The first liners were ordinary mild steel. Since start-up, all of the original steel liners have worn out. The wear back liners are being replaced with higher wear resistant liners which are giving much better performance. Both Astroloy and the CR 25 wear resistance metal alloys have been used. The CR 25 alloy is currently showing good wear resistance, but it is also the most expensive. It is too early to predict what will be the most cost effective liner at Ames. This will be determined as the plant gains more experience.

Various liner materials for pneumatic liner conveying RDF were tried by the Union Electric Company during the St. Louis tests. The results of these tests are reported1/ and indicate that glass fiber reinforced epoxy resin lined with alumina ceramic or R35 abrasion resistance cast metal were suitable materials to reduce elbow wear. However, the Astroloy and CR 25 material being used at Ames were not tried at St. Louis and therefore no direct comparisons can be made.

Pneumatic Conveying from Storage Bin to Boilers--

There are four lines from the Atlas bin to the boilers. These are 203 mm (8 in.) diameter in size and an average 137 m (450 ft) long. Actual lengths of the lines vary depending upon the boiler to which the pneumatic conveying line is directed. The number of elbows varies from four to seven, depending again upon which boiler is fed.

From start-up to the end of July 1976, a period of 11 months, approximately 200 pluggages have occurred. This is an average of nearly once per day. Pluggage occurs both in the pneumatic conveying lines and the airlock feeders.

A great number of pluggages occurred in the airlock feeders during a 2-1/2 week period in March 1976, when the second stage shredder was out of service due to a bearing failure and a single stage shredding was used. Downtime for any particular conveying line and airlock feeder is approximately 1 hr to clear the plug.

Plant personnel feel that the new higher resistance wear back liner discussed in the preceding section is helping to reduce the number of plugs and that the pluggage problem should improve as more elbow liners are replaced.

1/ Gorman, P. G., L. J. Shannon, M. P. Schrag, and D. E. Fiscus. "St. Louis Demonstration Final Report: Power Plant Equipment, Facilities, and Environmental Evaluations," Prepared for U.S. Environmental Protection Agency by Midwest Research Institute, Kansas City, Missouri, July 1977.

As the original steel elbows wore, they became rough inside, and when a hole was worn through, it was often patched. The rough inside surface and the jagged edges of a patched hole tend to catch and hold RDF as it passes around the elbow. The new liners being installed should remain smooth much longer and should not cause as much catching of RDF and ultimate plugging of the pneumatic conveying lines. However, time will tell if this theory is correct.

Since May 14, 1976, a record has been kept showing the location and exact nature of each pluggage. Tabulation of these data are presented in Appendix Table C-8.

Although conveying line pluggage is a serious problem requiring labor man-hours to clear plugs, the time available for burning RDF has not been adversely affected. While one line is being cleared, RDF conveying can be continued on the other lines.

Storage Bin

The bottom of the Atlas bin is 25 m (83 ft) in diameter. RDF is moved to the four drag chain conveyors feeding the four pneumatic conveying systems by a sweep conveyor operated by a large flexible member roller assembly installed on the circumference of the Atlas bin. This roller assembly is in turn powered by two variable speed motors located 180 degrees apart.

This flexible member roller assembly is supported on rollers moving in a track installed on the circumference of the bin. By June 1976, this roller assembly had stretched enough due to use so that its rollers came in contact with some of the supporting structural steel members of the bin, causing excessive wear of the rollers and structural steel, and jamming of the assembly. Two days of downtime were experienced due to this situation. The problem was solved by having the bin manufacturer adjust and thighten the roller assembly.

The point of this discussion is that in future such installations, adjustment of the Atlas bin sweep conveyor should be made early after start-up and could require periodic adjustment thereafter.

In July 1976, a second period of downtime of 1 day occurred due to breakage of the roller chain drive between the sweep conveyor roller assembly and one of the variable speed motors.

Major Fire in the Processing Plant

On Saturday morning, November 6, 1976, at approximately 4 a.m., a fire was discovered in the processing area of the plant. Firemen arrived within minutes and had extinguished the fire by 6 a.m. The exact cause of the fire is unknown, though spontaneous combustion is considered to be the likely cause. The most serious damage was sustained by electrical wiring, necessitating a 2-week period to complete electrical repairs. Several electric motors, insulation on water pipes,and control room equipment were severely damaged. The plant was not operational until November 22, 1976. During the 2 weeks, employees cleaned and repaired much of the damage. All refuse received during this period was diverted to the landfill. A further discussion of the damage caused by the fire is contained in Appendix Table C-1f.

RAW REFUSE RECEIVED

Raw refuse is delivered to the processing plant by a variety of vehicles including private cars, pickups, and trucks. The City of Ames does not provide citizens with municipally controlled refuse pickup service; hence, private commercial operators of refuse pickup are the major delivery system. Figure 18 shown earlier in this section provides a schematic of the plant. Deliveries of refuse are unloaded at the tipping floor. At this point, certain refuse items are segregated such as large appliances, paper, and wood which is subsequently sold. The balance of the refuse is processed. Deliveries in commercial trucks are weighed prior to dumping and after unloading to obtain a net load weight. This procedure is not practical for deliveries in cars and a separate entrance and egress is provided for them. Private cars enter the tipping floor through a gate, after depositing the $0.50 charge into the meter.

Private Car Deliveries

Since private car deliveries are not weighed, part of the study test program involved weight sampling on several days to provide an estimate of refuse quantities delivered from this source. The procedure used involved deposit of the refuse in a special location on the tipping floor. From this point, the plant front end loader scooped up the material and put it into a dump truck which was then weighed. The number of truck loads weighed each day was totaled, then divided by the number of private cars through the metered gate, yielding a daily average weight per private car.

During the period between June 14 and August 30, 1976, private car deliveries were monitored on 51 days. These data are presented in Appendix Table C-2, showing the average weight of 92.4 kg/private vehicle and the expected range of weights. The value of 92.4 kg/private vehicle has been used to determine incoming quantities from this refuse source.

Statistical analysis shows that variability from day to day results in an expected range of ± 14.2 kg/vehicle which is 15% of the mean value of 92.4 kg/vehicle. However, since the total private refuse per day is less than 10% of the total daily raw refuse delivered to the processing plant, a 15% range in the average weight of raw refuse per private vehicle would not have less than a 1.5% effect on the total plant material balance.

Statistical analysis of Table C-2 for any trends present revealed that there was no correlation between kilogram per vehicle and day of the week.

Therefore, no adjustment between kilogram per vehicle and day of the week need be made, and the average value of 92.4 kg/vehicle can be applied uniformly, regardless of day. However, including all the data, there was an 80% statistical correlation between the number of private vehicles and day of the week. This relationship is shown in Figure 23. The 4th of July weekend data are not typical of the rest of the data. The 4th of July was Sunday and Monday, July 5th was an official holiday. Deliveries on Saturday, July 3rd were unusually low for Saturday while deliveries on the Friday preceding and the Tuesday following the holiday weekend were more typical of Saturday deliveries. When July 2nd, 3rd and 6th data were discounted, the statistical correlation became 88% for a parabolic curve of the type $Y = Ao + A_1X + A_2X^2$.

The important conclusion is that the differences between days Monday through Friday, the normal 5-day workweek, are small. However, as would be expected, there is a sharp increase in the number of private vehicles on Saturday, presumably because individuals have free time on Saturday to make the trip to the refuse processing plant. Days immediately preceding or following holidays are special cases and do not necessarily correspond to what could be normally expected for that day of the week.

Truck Deliveries

Truck delivery accounts for the majority of the total refuse received at the processing plant by weight. It includes refuse that comes from a variety of sources. Table 18 below provides a percentage breakdown of refuse sources during the months of June through November 1976.

TABLE 18. PERCENT OF RAW REFUSE WEIGHT BY SOURCE

Source	(%)
Commercial licensed haulers	61
Nonscale refuse	17
City of Ames	11
Private industry	6
Private commercial haulers	1
All others	4
Total	100

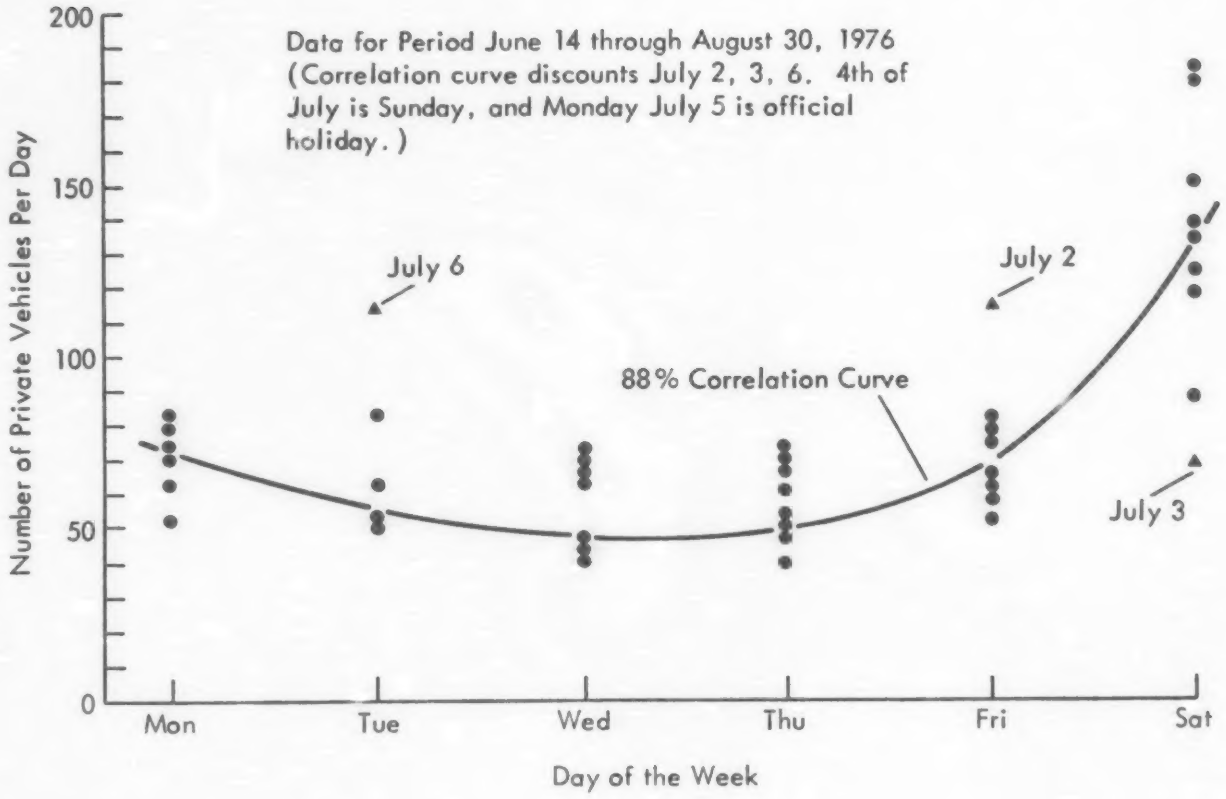

Figure 23. Number of private vehicles delivering raw refuse to the refuse processing plant versus day of the week.

Summary of Refuse Received

A summary of the monthly incoming refuse is presented in Appendix Tables A-1 and A-2, and Figure 12. There is no recognizable significant pattern. The reason for the low figure in November is because of the 2-week downtime resulting from the fire that month.

An analysis of daily incoming refuse during June through October indicates that Tuesdays and the last 4 days of each month tend to be the heaviest receiving days. Wednesdays and Thursdays are days of the week which are the lowest in Mg of refuse received, typically by about 10 to 15%. There do not appear to be any other discernible patterns.

The volume of refuse received at the plant for the period January 1 through December 31, 1976, was 37,136 Mg. The design of the plant was planned to accommodate nearly 94,000 Mg/year, operating on a one-shift 5 day workweek.

In 1976, 37,137 Mg of raw refuse was processed, and therefore, clearly, the plant has the capability to process additional volumes of refuse. Consideration is being given to alternatives that will increase refuse deliveries and plant throughput, such as the establishment of agreements with additional communities to process their wastes.

PROCESSING PLANT LABOR

Fourteen people are required to administer and operate the refuse processing plant as listed in the following manning table (Table 19). Twelve of the 14 are direct labor, though not all are full-time employees.

Job Descriptions

Job descriptions for each work station in the processing plant are presented in Appendix Table C-3. Almost all full-time personnel are frequently required to work at more than one station, as required, during a typical operating day. Training for virtually all stations is conducted on-the-job. The notable exception is specialized maintenance (electrical, hydraulic, etc.), and operation of the plant control panel. Typically, only the chief operator and the plant superintendent work at the control panel, since special training and a thorough knowledge of the total system are required.

Analysis of Labor Allocation

The distribution of direct plant labor among 20 categories of work is presented in Table 20 on a monthly basis for the period June 1 through December 31, 1976. Totals for this period indicate that the bulk of the

TABLE 19. MANNING TABLE FOR REFUSE PROCESSING PLANT

No. of employees	Title	Full- or part-time	Category
1	Public works director[a]	Part	Administration
1	Plant superintendent	Full	Direct supervision
1	Chief operator	Full	Direct labor
1	Front-end loader operator	Full	Direct labor
1	Truck driver	Full	Direct labor
2	Maintenance I	Full	Direct labor
1	Maintenance II and electrician	Full	Direct labor
1	Maintenance II	Full	Direct labor
4	Clean-up	Part	Direct labor
1	Secretary and tour guide	Part	Direct labor
14	(8 full-time - 6 part-time)		

[a] 15% of public works director's time assigned to refuse operations.

TABLE 20. SUMMARY OF PROCESSING PLANT DIRECT LABOR HOURS
(Does not include plant superintendent)

Operation	Direct labor hours by month															
	June		July		August		September		October		November		December		Total	
	Hr	%	Hr	%	Hr	%	Hr	%	Hr	%	Hr	%	Hr	%	Hr	%
Operating front-end loader	261.5	12.4	247.0	12.1	241.0	11.7	216.0	11.2	229.0	12.1	108.0	10.0	242.0	11.9	1,544.5	11.8
Tipping floor	215.25	10.2	224.75	11.0	207.25	10.1	147.0	7.6	194.0	11.0	60.5	5.6	211.0	10.5	1,259.7	9.6
Control room	203.5	9.6	91.0	4.4	216.5	10.5	179.0	9.2	179.0	10.0	100.5	9.3	221.0	10.9	1,190.5	9.1
Secretarial and tours	97.5	4.6	83.5	4.1	64.0	3.1	70.0	3.6	78.0	4.0	37.0	3.4	94.0	4.6	524.0	4.0
Shredders and hammers	46.0	2.2	90.0	4.4	126.0	6.1	60.0	3.1	43.0	2.0	37.0	3.4	132.0	6.5	534.0	4.1
General operations and shredder grates	424.25	20.2	433.75	21.3	454.0	22.2	473.0	24.4	401.0	21.2	321.5	27.8	401.0	19.8	2,908.5	22.2
ADS	30.0	1.4	6.0	0.3	6.0	0.3	0.0	0.0	0.0	0.8	9.0	0.8	111.0	5.6	162.0	1.2
ADS drag conveyor	74.25	3.5	95.5	4.7	122.5	6.0	0.0	0.0			3.0	0.3	29.0	1.4	324.3	2.5
Screw feeder	19.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	21.0	1.0	2.0	0.2	0.0	0.0	42.5	0.3
Fe-metal magnets	4.0	0.2	0.0	0.0	65.5	3.2	0.0	0.0	0.0	0.0	0.0	0.0	32.0	1.6	101.5	0.8
Al-metal system	32.5	1.5	82.5	4.1	25.0	1.2	0.0	0.0	16.0	0.8	2.5	0.3	44.0	2.2	202.5	1.5
Conveyors	41.5	2.0	8.0	0.4	6.0	0.3	0.0	0.0			22.3	2.1	40.0	2.0	117.8	0.9
Wood chip system	11.5	0.5	15.75	0.8	12.0	0.6	9.0	0.5	29.0	1.5	6.5	0.6	13.0	0.2	96.7	0.7
Recovered metal	48.5	2.3	24.5	1.2	34.5	1.7	14.0	0.7	27.0	1.4	0.0	0.0	0.0	0.0	148.5	1.1
Rejects	73.0	3.4	46.25	2.3	64.25	3.1	75.0	3.9	84.0	5.0	55.3	5.1	79.0	3.9	476.8	3.6
Landfill	35.0	1.7	52.75	2.6	37.5	1.8	19.0	1.0	10.0	0.5	3.5	0.3	25.0	1.2	182.7	1.4
Maintenance	42.0	2.0	104.5	5.1	5.0	0.2	128.0	6.6	60.0	3.0	16.5	1.5	58.0	2.9	414.0	3.2
Cleaning process area	341.25	16.1	326.75	16.0	259.0	12.6	414.0	21.4	437.0	24.2	204.0	18.9	203.0	10.0	2,185.0	16.7
Janitorial	84.0	4.0	60.25	3.0	74.0	3.6	79.0	4.1	33.0	1.7	45.5	4.2	57.0	2.8	432.8	3.3
Miscellaneous	31.0	1.5	44.25	2.2	35.5	1.7	53.0	2.7	12.0	0.6	44.4	4.2	41.0	2.0	261.2	2.0
Total	2,116.0	100.0	2,037.0	100.0	2,055.5	100.0	1,936.0	100.0	1,853.0	100.0	4,079.0	100.0	2,033.0	100.0	13,109.5	100.0

labor requirement is devoted to general operations and shredder grates (22.2%), followed by cleaning of the process area (16.7), operation of the front-end loader (11.8%), and tipping floor (9.6%), and the control room operation (9.1%). These categories account for nearly 70% of the total work performed at the plant. Prior to September, maintenance was unscheduled, i.e., conducted only after breakdown. Beginning in September, a program of regularly scheduled preventative maintenance was begun. This included scheduled lubrication, adjustment when necessary of mechanical drives, conveyor belt tension, etc., and most importantly careful inspection of equipment for loose or worn parts which are then tightened or replaced as necessary.

Data are presented in Figure 24 comparing overtime, regular and total hours of work at the plant. While regular working hours have remained relatively stable over the period, overtime has diminished, indicating improved management and increased working efficiencies.

During the period June 1 through December 31, 1976, the labor hours of input per Mg of refuse processed at the plant averaged 0.61 hr/Mg. For each month, the figures were: June - 0.63; July - 0.64; August - 0.62; September - 0.61; October - 0.54; November - 0.62; and December - 0.65.

Labor Turnover and Working Conditions

Labor turnover experience at the processing plant has been extremely low for full-time employees, with the exception of the Maintenance I position. A considerable degree of employment loyalty exists among full-time employees, undoubtedly because of the uniqueness of the processing plant and the attention it has received within the community. Full-time employees appear to be satisfied with the work and demonstrate a high degree of willingness to share work responsibilities, particularly in the area of maintenance.

Part-time employee turnover has been high, with the exception of the position of the secretarial and tour guide position. The janitorial position has changed on the average of two to three times per year. Reasons given for the high turnover among part-time employees are two-fold: (a) most part-time employees consider the job as only temporary and leave when better positions are found or when no longer needed at the plant, and (b) most of the part-time employees have been students at the university, who leave due to graduation or changes in class schedules.

Working conditions at the processing plant vary. Personnel who work in the control room are afforded the conveniences and comforts of inside work. The remainder of the plant can be divided into two working areas and working conditions are discussed in each as follows:

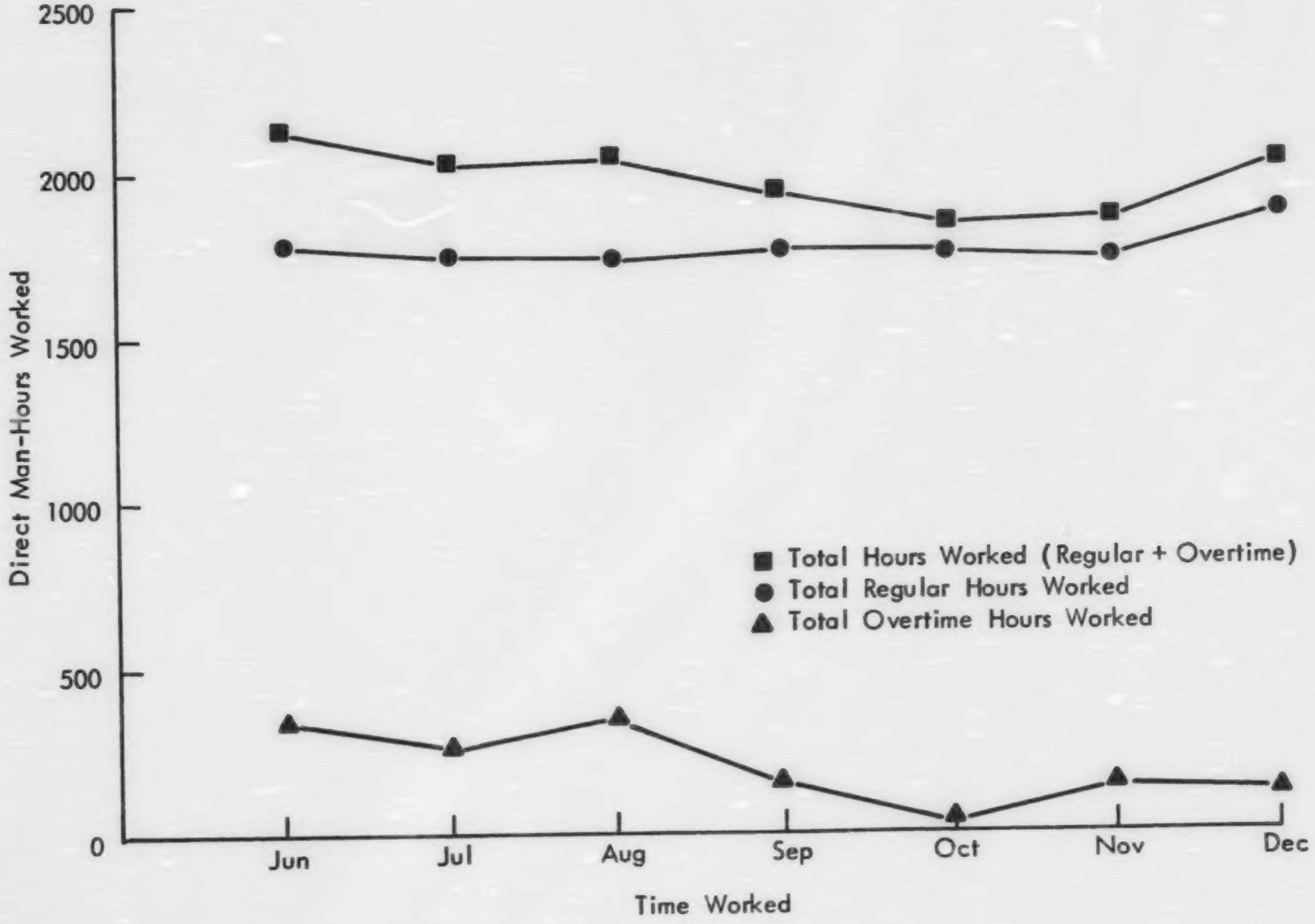

Figure 24. Total direct man-hours worked in refuse processing plant.

Tipping Floor--

The most serious factor is exposure to cold weather in the winter. Large doorways permit windchill as well as low temperatures. To quote an operator, "When it's 20 below outside, it's 22 below on the floor." This has been cited as a reason for turnover in one of the Maintenance Man I positions. During the summer the air is occasionally somewhat dusty, but the plant personnel do not feel this is a serious problem. Noise levels are occasionally high; noise surveys are planned for 1977. Ultraviolet light fly traps are used to control flies during the summer.

Processing Plant--

The conditions inside the processing plant contains several significant features. These include: dust, noise, and occasional flying debris. Precautions include the use of hard hats, dust filter masks, safety glasses, gloves, and specified monitoring locations on steel grates. All grates and ladders have safety railings.

One important provision is assuring the safety of operating personnel in the processing plant is readily accessible and reliable communication with the chief operator. Telephones are located at many stations in the processing plant, including all monitoring areas. In addition, there is a P.A. system which is clearly audible over the noise created by process machinery. Operators monitoring the process are never out of immediately available contact with the chief operator. They can give or receive a message at any time. Battery-powered, portable radios are also kept for this purpose.

In accordance with OSHA requirements, a siren has been provided which sounds when each major item (primary or secondary shredder, etc.) or set of items (group of conveyors) is started up. In starting up the process, the siren sounds 10 times altogether. The siren is coupled to start-up controls on the console and sounds automatically as equipment is started.

PROCESSING AND DOWNTIME

This part of the report provides information about plant operating hours and the amount of downtime incurred. The first section will discuss processing, the second downtime, and finally, a comparison of the two.

Plant Processing

During the months of June through December 1976, records have been maintained on plant operations. Detailed data are presented in Appendix C. The raw refuse in-feed conveyor (Conveyor C-1) run-time is recorded giving the actual time raw refuse was being shredded each day. The feeder for the pneumatic conveying system, which carries the refuse derived fuel (RDF) from the processing plant to a storage bin is also recorded. The processing plant cannot operate unless the pneumatic conveying system is in operation. Therefore, this last meter records the total time the plant was in operation.

From June 1 through December 31, 1976, total plant operating time was 946.5 hr or 7.01 hr/day. Total operating time for the raw refuse in-feed conveyor (actual processing time) was 736.1 hr, or 5.45 hr/day. A use factor can consequently be calculated by dividing in-feed hours by total operating hours. For the entire period, the use factor was 77.8%.

The in-feed conveyor daily hours are less than the plant operating hours due to downtime on the various items of equipment. During normal processing, the in-feed conveyor is stopped when downtime occurs. The balance of the plant is left in operation except for the particular component of machinery causing the downtime, which may, or may not, be shut down depending on the nature of the problem.

The use factor will never be 100% even without any downtime because the pneumatic conveying system must be started first before any of the plant conveyors can be operated. Also, when the plant is shut down at the end of each day, a timer allows the pneumatic conveying system to continue operating for a few minutes to clear the pneumatic conveying pipeline.

Downtime

Records have been maintained at the plant on the number of hours the plant was not operating because of subsystem malfunctions. This information includes a breakdown of downtime by subystems; e.g., shredders, ferrous metal separation, nonferrous metal separation, the air density separation (ADS) system, the associated conveyors of each, and the tipping floor.

Table 21 presents the total monthly downtime for the period from June 1 through December 31, 1976, and the percent of this total attributable to each of the five subsystems. Downtime is defined as the time the total system cannot be operated because a subsystem is malfunctioning, considering as well, the amount of refuse delivered to the plant for 1 day. For example, if only 50 Mg are delivered to the plant, downtime is only the amount of time needed to process 50 Mg, not the full 8 hr. Further, necessary maintenance is not considered downtime; e.g., hammer changes, and the time required to change the trailer which collects recovered metals. Also, if a subsystem is inoperative, but does not affect the operation of the rest of the system, the time is not considered downtime.

From Table 21, it is clear that the ADS subsystem is the largest contributor of downtime, accounting for nearly 58% of the total. Most of the problems with the ADS subsystem are caused by the ADS drag conveyor. The second major contributor is the shredder subsystem which accounts for 30% of the total.

TABLE 21. MONTHLY SUMMARY OF PLANT DOWNTIME BY SUBSYSTEM

Month	Shredder		ADS		Ferrous		Nonferrous		Tipping floor		Totals	
	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
June 1976	7.26	19.4	28.58	76.4	0.50	1.3	0.25	0.7	0.83	2.2	37.42	100.0
July	14.07	41.8	15.40	45.8	1.94	5.8	0	0	2.23	6.6	33.64	100.0
August	15.55	49.3	10.05	31.9	3.93	12.5	0	0	2.01	6.3	31.54	100.0
September	9.04	34.0	13.09	49.2	1.48	5.6	0	0	3.00	11.2	26.61	100.0
October	2.96	13.1	17.54	77.3	2.18	9.6	0	0	0	0	22.68	100.0
November[a]	5.80	34.6	7.51	44.8	3.46	20.6	0	0	0	0	16.77	100.0
December	7.62	20.0	26.82	70.3	2.05	5.4	0	0	1.68	4.4	38.17	100.0
Total[a]	62.30	30.1	118.99	57.5	15.54	7.5	0.25	0.1	9.75	4.7	206.83	100.0

[a] Does not include downtime attributable to the fire. Downtime caused by the fire is presented below.

November	85.80	20.6	87.51	21.0	83.46	20.0	80.00	19.2	80.00	19.2	416.77	100.0
Total	142.30	23.4	198.99	32.8	95.54	15.7	80.25	13.2	89.75	14.8	606.83	100.0

For descriptive purposes, downtime caused by the fire at the processing plant in November is presented as a footnote to the table. This incident is considered extraordinary, however, and should be used accordingly.

Summary of Plant Processing and Downtime

During the period of the study (June through December 1976), the plant was manned and operational 946.5 hr. Actual processing time was 736.1 hr, or 77.8% of the time. The amount of refuse processed during the period was 21,360 Mg. As shown in Table 22, the average Mg of refuse processed was 22.6/available hour of time, and 29.0/hr of actual processing time.

Also during the period of the study, records indicate that the plant was down 21.9% of the time, in accordance with the definition of downtime presented above and relative to the total hours the plant was manned and operational. Not included in Table 22 is the number of hours when the plant was not operational because of the fire between November 6 and 21. The inclusion of these hours, which raises the total to 606.83 hr of downtime, results in a downtime factor of 39.1%.

ELECTRIC POWER UTILIZATION

Electric power consumption has been recorded for the total plant and seven individual major items of equipment for the period June 1 through December 31, 1976. These data are summarized by month in Table 23. Weekly electricity consumption figures are included herewith as Appendix Table C-5. For purposes of comparison, consumption of electricity is presented by major equipment piece and indirect plant (i.e., lighting, ventilation, heat, etc.) both in terms of kilowatt hours of use and relative percentages. A listing of the major electric motors installed in the plant is presented in Appendix Table C-6.

As expected, the shredders and storage bin were the major electricity consumers, accounting for 26.3 and 18.6%, respectively. The single largest consumption category, however, was indirect. This item increased significantly during the months of November and December primarily because of the use of electric resistance heating and the decision to maintain lighiting in the plant 24 hr/day to allow visual plant inspection of night watchmen checking for possible fire.

The Shredders

The second stage shredder uses almost twice as much power as the first stage shredder. The weight of refuse shredded per day is less in the second stage shredder by the amount of ferrous metal removed by the magnetic belt between the first and second stage shredders. Both shredders are operated by 746 kw (1,000 hp) motors. Therefore, the question is raised: Can the

TABLE 22. PLANT OPERATING HR DOWNTIME AND REFUSE PROCESSED/OPERATING HR
(June 1 through December 31, 1976)

Month	Total plant operating hr	Downtime hr	% of downtime to plant operating hr	Actual processing hr	Refuse processed (Mg)	Process Rate	
						Mg/operating hr	Mg/processing hr
June	125.2	37.42	29.9	98.1	3,354	26.8	34.2
July	133.6	33.64	25.2	99.1	3,194	23.9	32.2
August	157.4	31.54	20.0	121.5	3,314	21.1	27.3
September	148.2	26.61	18.0	120.6	3,198	21.6	26.5
October	142.0	22.68	16.0	112.2	3,420	24.1	30.5
November	77.0	16.77	21.8	54.1	1,739	22.6	32.1
December	163.1	38.17	23.4	130.5	3,141	19.3	24.1
Total[a]	946.5	206.83	21.9	736.1	21,360		
Average						22.6	29.0

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[a] Excludes the downtime due to the fire in November.

TABLE 23. WEEKLY ELECTRIC POWER CONSUMPTION FOR REFUSE PROCESSING PLANT AND STORAGE BIN

Month	First stage shredder	Second stage shredder	ADS fan	Pneumatic conveying blower (to Atlas bin)	Processing plant indirect[a]	Storage bin (storage and pneumatic conveying to boiler)	Total processing plant and storage bin	% by month
June								
kw-hr	19,594	36,371	14,003	12,184	65,953	41,125	189,530	12.5
%	10.3	19.4	7.4	6.4	34.8	21.7	100.0	
July								
kw-hr	23,567	42,509	14,096	11,894	86,340	41,849	220,255	14.5
%	10.7	19.3	6.4	5.4	39.2	19.0	100.0	
August								
kw-hr	21,486	40,314	15,277	12,381	77,560	39,902	206,920	13.6
%	10.4	19.5	7.4	6.0	37.5	19.3	100.0	
September								
kw-hr	21,840	48,137	15,377	12,703	82,010	72,788	222,855	14.7
%	9.8	21.6	6.9	5.7	36.8	19.2	100.0	
October								
kw-hr	21,420	30,660	12,810	11,060	79,715	42,960	198,625	13.1
%	10.8	15.4	6.5	5.6	40.1	21.6	100.0	
November								
kw-hr	16,520	15,400	8,190	6,720	102,520	26,000	175,350	11.6
%	9.4	8.8	4.7	3.8	58.5	14.8	100.0	
December								
kw-hr	25,620	36,680	16,870	12,810	163,325	47,760	303,065	20.0
%	8.5	12.1	5.6	4.2	53.9	15.8	100.0	
Total								
kw-hr	150,047	250,371	96,623	79,752	657,423	282,384	1,516,600	100.0
%	9.9	16.5	6.4	5.3	43.3	18.6	100.0	

[a] Includes heat, light, ventilation, maintenance (e.g., welding, tools), conveyors, feeders and metals recovery.

work load be more uniformly distributed between the two shredders by installing smaller grate sizes in the first stage shredder? Smaller grate sizes in the first stage shredder will increase its power consumption. What is not known is the exact relationship of particle size to power usage for the second stage shredder. It would be undesirable to increase total kilowatt-hours for both shredders (Shredder No. 1 plus Shredder No. 2). However, if an electric power use increase for the first stage shredder due to smaller grate size were followed by a corresponding decrease in the second stage electric power consumption, then this would be a desirable operating condition from a power standpoint.

Another question is what would be the effect on hammer wear. The preceding section on shredder maintenance shows that the first stage hammer working life is slightly less than twice the working life of the second stage shredder hammers. Also, it requires more man-hours per Mg of refuse processed to change and balance hammers in the second stage shredder than in the first stage shredder. Therefore, a decrease in the first stage hammer life, if it resulted in a corresponding increase in the second stage shredder hammer life, would be beneficial to the shredder system operations.

Electric Power Consumption

The data provided in Table 24 are presented to establish a basis for comparison with other processing plants. Power consumption averaged 2,060 kw-hr/actual processing hour. This figure drops to 1,602 kw-hr of consumption/hour the plant was manned and operational. Electric power consumption per Mg of refuse processed during the period averaged 71.0 kw-hr.

REFUSE DERIVED FUEL (RDF) CONVEYING SYSTEM AND STORAGE BIN

This part of the total operation is, at least in part, unique to the Ames facility because of the nearby proximity of the processing plant to the electric power generating plant. RDF transport is by pneumatic conveying from the processing plant to the storage facility and also from the storage facility to the electric power plant boilers.

Table 25 presents a monthly summary of the operation of the RDF pneumatic conveying system, drawn from daily figures included in Appendix Table C-7. The period covered is from June 2 through December 31, 1976.

The use factor derived at the bottom of the table provides an indication of the reliability of the conveying system and storage bin or 84.2% of the total available operating hours during the period not including the November fire downtime. The resulting downtime for the system may be caused by malfunction of the pneumatic line system or the equipment in the storage bin. Daily records of the causes of downtime and maintenance for the pneumatic system and the storage bin are presented in Appendix Tables C-8 and C-9. A summary of this information is presented on a monthly basis in Table 26.

TABLE 24. ELECTRIC CONSUMPTION RATIOS (June 1 through December 31, 1976)

	(in kw-hr)		
Month	Electric consumption/ operational hr	Electric consumption/ processing hr	Electric consumption/ Mg of refuse
June	1,514	1,932	56.5
July	1,649	2,223	69.0
August	1,315	1,703	62.4
September	1,504	1,848	69.7
October	1,399	1,770	58.1
November	2,277	3,241	100.8[a]
December	1,558	2,322	96.5
Average	1,602	2,060	71.0

[a] Includes electric power used in maintenance activities associated with fire damage repairs.

Note: Increases in November and December are partially attributable to additional space heating requirements. The plant is heated with electric resistance heat.

TABLE 25. RDF CONVEYING SYSTEM-OPERATING HR AND COMBUSTION RATE MONTHLY SUMMARY

	Pneumatic conveying line hr of operation						
Month	A	B	C	D	Hr RDF burned[a]	RDF burned (Mg)	Average burned rate (Mg/hr)
June	537.5	9.1	0.4	513.0	568.9	2,079.1	3.7
July	567.9	0.2	0.3	566.2	623.5	2,445.5	3.9
August	578.2	3.2	3.9	507.9	600.1	2,597.7	4.3
September	575.7	0.0	0.0	632.1	643.9	2,464.4	3.8
October	625.9	0.0	0.0	619.3	634.8	2,684.0	4.2
November	300.8	0.0	0.0	308.2	312.6	1,396.4	4.5
December	600.0	0.0	0.0	609.2	636.3	2,289.6	3.6
Total	3,786.0	12.5	4.6	3,755.9	4,021.1	15,956.7	4.0[b]
Use factor %[c]	79.3	0.3	0.1	78.6	84.2		

[a] Maximum hour total system was in operation on daily basis.

[b] Total Mg/total hour. Not arithmetic average of column.

[c] Percent of available hour. Available hour = 199 days (24 hr/day = 4,776) excluding 14 days downtime resulting from fire in November.

TABLE 26. SUMMARY OF DOWNTIME FOR PNEUMATING CONVEYING LINES AND STORAGE BIN
(June 1 through December 1976)

	Pneumatic conveying system downtime				Storage bin			
Month	Line A	Line D	Hr when both lines down simultaneously[a/]	% of available operating hr[b/]	Hr	% of available operating hr[b/]	Grand total of downtime	% of available operating hr
June	59.8	69.7	20.6	3.3	55.4	8.0	76.0	10.9
July	73.3	58.2	21.4	2.9	21.8	2.9	43.2	5.8
August	39.7	105.6	7.2	1.0	75.5	10.1	82.7	11.1
September	68.6	21.4	7.9	1.1	1.3	0.2	9.2	1.3
October	21.6	24.1	0.7	0.1	15.9	2.1	16.6	2.2
November[c/]	14.1	8.6	0.3	0.1	0.0	0.0	0.3	0.1
December	62.3	53.3	19.3	2.6	4.4	0.6	23.7	3.2
Total	339.4	340.9	77.4	1.6	174.3	3.6	251.7	5.30

a/ Since four lines are available for use, the pneumatic system can remain operational unless all lines are not functional. Hence, the pneumatic subsystem downtime is counted only when all lines are not operational.

b/ Days per month refuse could have been burned x 24 hr.

c/ Reduced hours resulting from November 6 fire in processing plant.

Of the problems encountered with the pneumatic conveying system, the most prevalent cause of downtime is stoppage of the feeder with pieces of wire, rubber and wood, accounting for slightly more than 50% of the failures. Plugged lines are another source of problems, as are repairs to elbows in the line. Downtime of the storage bin is not very prevalent, although the bin was down several days in June. The most usual occurrence is problems with the sweep drive. For both subsystems, the amount of downtime has shown evidence of decreasing during the year.

The hours of labor required to repair and maintain the pneumatic conveying system for the June through December period totaled 1,184.3 hr, 430.8 of which were paid on an overtime basis. Similarly, hours of labor for repairing and maintaining the storage bin totaled 544.5, 92 of which were paid at overtime rates.

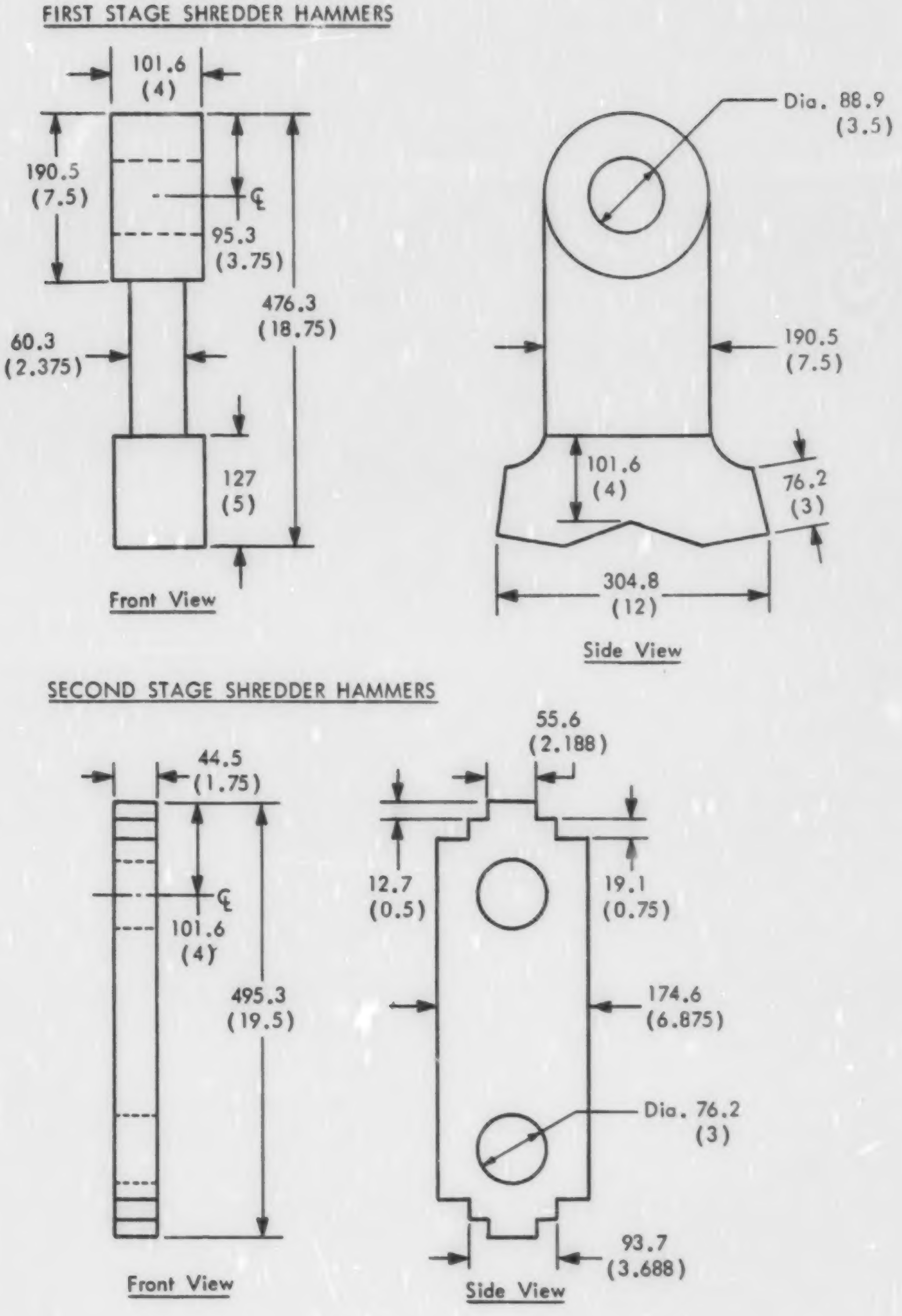
OTHER PLANT EVALUATIONS

This part of the report presents four items which individually are not lengthy enough to warrant a section unto themselves, but are considered pertinent to the study. Specifically, shredder maintenance, refuse throughput, plant water consumption, and net electric power generation are discussed.

Shredder Maintenance

During the course of the study, the hammers on Shredder No. 1 were replaced once, and three times on Shredder No. 2. Each shredder has 48 hammers, whose dimensions are shown in Figure 25. Cost and working life experience to date for these hammers are as follows:

	First stage shredder	Second stage shredder
Number of hammers	48	48
Weight of each hammer (kg)	69	24
New cost of each hammer ($)	146	49
Cost ($/kg)	2.12	2.04
Number of working faces/hammer	2	4
Useful life		
Mg each face	10,000	3,000
Total (Mg)	20,000	12,000


FIRST STAGE SHREDDER HAMMERS
101.6 (4)
190.5 (7.5)
℄
95.3 (3.75)
476.3 (18.75)
60.3 (2.375)
127 (5)
Front View
Dia. 88.9 (3.5)
190.5 (7.5)
101.6 (4)
76.2 (3)
304.8 (12)
Side View
SECOND STAGE SHREDDER HAMMERS
44.5 (1.75)
℄
101.6 (4)
495.3 (19.5)
Front View
55.6 (2.188)
12.7 (0.5)
19.1 (0.75)
174.6 (6.875)
Dia. 76.2 (3)
93.7 (3.688)
Side View

Note: All Dimensions in mm and (Inches)

Figure 25. Dimensions of shredder hammers.

Time required to change and balance hammers

	Date changed	Plant time (hr)	Labor (man-hr)
First stage shredder	8/7 and 9/11	22.4	89.5
Second stage shredder	7/30	12.4	49.5
	9/14	4.1	16.5
	12/8	3.0	12.0

As the above information shows, plant maintenance personnel have become considerably more proficient in changing the shredder hammers. When the first stage hammers were changed for the first time, the excessive labor hours required to perform the task were partially attributable to difficulties in removing the hammer shaft from the shredder. Maintenance personnel believe that the hammers were used too long, causing the shaft to warp.

In July 1976, the curtains in both shredders were replaced with new rubber curtains. Following are the material costs and labor hours to do this work.

	First stage shredder		Second stage shredder	
Material	Number	Total ($)	Number	Total ($)
Curtains	3	780	2	600
Hangers	3	54	2	36
Hanger rod	1	6	1	6
Total		840		642

	Number of men	Total man-hours	Number of mean	Total man-hours
Labor	6	16.5	3	16.5

The total for both shredders was $1,482 and 33 man-hours labor.

Summary of Plant Mass Balance

The purpose of this section is to present some idea about processing plant input and output, that is, an estimated mass balance for refuse. Unfortunately, the system is not equipped with a scale to weigh the actual amount of RDF after processing. However, a means was provided to allow periodic sampling on a mass-density basis. The problem with such a measure is that the mass-density of RDF undoubtedly varies significantly, if visual observation is reliable. Nevertheless, the data presented in Table 27 provide a rough approximation of refuse mass measurement error. The average for the period June 1 through December 31, 1976, is about 11%. Some of this loss may be a problem of inaccurate measurement rather than material loss. For example, incoming refuse delivered by private automobiles is an average figure based on sampling (see Appendix Table C-2) and can vary significantly. In addition, commercial vehicles tare is a one-time measurement and vary because of fuel carry. This compares with a loss factor at the St. Louis pilot plant of 6%. The refuse processing plant at Madison, Wisconsin, experienced a loss factor of 2 to 5%.

Another possible reason for the apparent discrepancy is that monthly "inventory" carryover figures are unavailable. The period under study is not sufficiently long for this difference, if any, to average out.

Net Electrical Power Generation

Table 28 presents information relevant to determining the net energy efficiency of the refuse processing plant. During the period June 1 through December 31, 1976, the refuse processing plant consumed slightly more than 1.5 million kw-hr, of electricity. The generation of electric power directly attributable to RDF for the period was 11.97 million kw-hr, yielding net power generated of 10.45 million kw-hr. For the period, this amounts to an average electricity content per Mg of refuse received of 489.1 kw-hr of power. If the electric power content is calculated on the actual amount of RDF fed into the boilers (15,957 Mg), the power content increases to 654.6 kw-hr/Mg.

TABLE 27. SUMMARY OF PLANT MASS BALANCE
(June 1 through December
31, 1976)

Month	Refuse received (Mg)	Recovered materials (Mg)	Refuse derived fuels by difference (Mg)	Refuse derived fuel by measure (Mg)a/	Apparent error/lossb/	
					Mg	%
June	3,354	547	2,807	2,079	728	26
July	3,194	537	2,657	2,446	211	8
August	3,314	478	2,836	2,598	238	8
September	3,198	471	2,727	2,464	263	10
October	3,420	600	2,820	2,684	136	5
November	1,739	268	1,471	1,396	75	5
December	3,141	498	2,643	2,290	353	13
Total	21,360	3,399	17,961	15,957	2,004	11

a/ Density sampling at storage bin.

b/ Difference between RDF by difference (theoretical) and measured RDF. Does not consider changes in monthly carryover or moisture and other losses.

TABLE 28. NET ELECTRICAL POWER GENERATION (June 1 through December 31, 1976) (in kw-hr)

Month	Processing plant electric power consumption	Electric power generation attributable to RDF[a]	Net electric power generated	Net electric power generated/mg of raw refuse received[c]
June	189,530	1,680,224	1,490,694	444.5
July	220,255	1,849,345	1,629,090	510.1
August	206,920	1,765,991	1,559,071	470.5
September	222,855	2,001,168	1,778,313	556.2
October	198,625	2,057,143	1,858,518	543.4
November[b]	175,350	985,485	810,135	465.9
December	303,065	1,633,061	1,329,996	432.4
Total	1,516,600	11,972,417	10,445,817	489.1

[a] Based on plant records of monthly amounts of RFD and coal used.

[b] Excludes 2-week period of downtime after fire November 6.

[c] Based on amounts of raw refuse received at processing plant, not Mg of RDF burned.

SECTION 7

ECONOMIC EVALUATION

The economic and financial aspects of the refuse processing plant at Ames are presented in this section of the report. Major areas of analysis include total plant investment and operating revenues and expenses. Most of the analyses cover the entire year of 1976. Operations prior to that time have been considered as start-up expense. Detailed expense analyses on each subsystem in the plant cover only the period from June 1 through December 31, 1976, since this is the term of the study.

The total capital investment in the Ames facility was $6.3 million, as defined for this study. First-year operating expenses were $1.15 million; revenues were $448,000. Based upon the amount of raw refuse received at the plant, the net cost per megagram of refuse received was $18.90.

Consideration of operating expenses and revenues should include the fact that this was the first full year of operating the plant. Though detailed information is not available to determine total effects of the learning curve, discussions with administrative personnel indicate that the experience gained to date will be advantageous in the future. Also, individual monthly expense data should be viewed as approximate. The City of Ames uses a cash accounting method, i.e., expenses are not recognized until paid. This accounts for unusually large expenses in some months, and correspondingly low expenses in other months. Standard accounting practice suggests use of the accrual method of accounting, i.e., recognizing expenses at the time they are incurred. In spite of this minor shortcoming, the totals for the year are valid.

The total expenses figures presented herein differ from those published by the City of Ames. The difference lies primarily in the method of accounting for interest, principal payments on the municipal bond issue used to finance the project, and depreciation. The City of Ames does not consider depreciation; rather, they are expensing the principal payments on the bonds. Also, they are expensing the full amount of interest paid on the debt. For this analysis, estimates of equipment useful life are considered and a depreciation schedule used to amortize the capital cost over the useful life. Also, the total interest on the indebtedness over the full 20 years has been annualized, i.e., evenly distributed.

CAPITAL INVESTMENT

The total initial investment in the solid waste processing project reached a level of $6.3 million as summarized in Table 29. A more detailed identification of individual cost elements is provided in Appendix Table D. Not included in the figures of Table 29 are: the cost of the plant feasibility study, working capital to operate the plant, nor initial inventory of supplies and replacement parts. Estimates on the last item could not be extracted from the accounting data. The city has used its general operating fund as a working capital source. The cost of the original feasibility study was about $20,000. The acquisition of a supplies and replacement parts inventory apparently was expensed within the first few months of operation, though the accounting records do not clearly reveal this. Hence, some of the inventory may be included in the "start-up expense" figure. Some basic assumptions used in developing the investment classifications are discussed below:

TABLE 29. SUMMARY OF CAPITAL INVESTMENT FOR THE AMES SOLID WASTE RECOVERY PLANT AND SYSTEMS

Investment category	Investment cost
Land for plant site	$ 82,841
Improvements on plant site (sewers, etc.)	10,227
Land for landfill	15,000
Processing plant and equipment	4,084,207
Auxiliary equipment, tools and parts inventory	164,827
RDF storage, firing equipment, and boiler modifications	1,599,127
Start-up expense	321,578
Total invested capital	$6,277,807

Land

This category includes the actual plant site at acquisition cost (purchased a few years prior to project commitment), 10 acres of landfill, and plant site improvements (street, sewer, etc.). The inclusion of improvements as part of land investment is made in accordance with generally accepted accounting principles.

Start-Up Expenses

Included within this category are all operating expenses, training, and interest expense incurred from start date through December 31, 1975, a period of about 4 months.

A 4-month start-up period may be considered longer than usual for some industries, but is not unreasonable, considering the unique character of the refuse processing plant. At the time the Ames plant went into operation in the fall of 1975, the St. Louis demonstration plant had ceased operations and no other refuse processing plants were in commercial operation. The Ames plant was applying a new technology, resulting in a 4-month start-up period. Future new plants, relying on a body of knowledge gained from existing plants such as Ames, may very well have shorter start-up periods.

Plant and Equipment

This classification is divided into three subclasses, i.e., the actual processing plant and operable equipment housed therein; the investment in auxiliary equipment, such as the front-end loader, tools, and spare parts; and the processed refuse storage bin, pneumatic conveyance, firing equipment, and power plant boiler modifications. This subclassification provides a logical systems breakdown according to use.

Depreciation and Amortization

The purpose of establishing such schedules recognizes the need to allocate investment costs over the estimated useful life of the equipment, or in the case of start-up expense, over a reasonable period of expected benefit accruing therefrom. Such allocations are not typically done for a public project, since no taxation benefits are involved. In reality, however, depreciable assets do have a finite life and investment cost should be allocated over the period of usefulness. Internal Revenue Service general guidelines have been used because no prior experience guidelines are available. Total annual depreciation is calculated to be $353,878, or $29,489 per month, using straight line methods.

Engineering Design

Expenses are shown separately where applicable in the detail schedules for each investment category. All other cost items have been detailed to the extent data were available.

The Ames system design was based upon the perceived needs of the community. However, in larger cities with higher daily volumes of refuse requiring larger refuse processing plants, certain economies of scale could possibly be achieved. For example, at Ames the installation of 50 Mg/hr shredders to process only 200 Mg/day of refuse at first seems expensive. However, municipal solid waste contains a sufficient amount of large bulky items which cause excessive maintenance and process downtime for shredders smaller than 50 Mg/hr. Therefore, the shredders at Ames are the smallest practical size that could be used, even though their capacity is not fully utilized.

A comparison of actual with estimated investment costs is presented in Table 30. Consideration should be given to the difficulty in developing cost estimates for a project of this size.

TABLE 30. COMPARISON OF PLANNED AND ACTUAL COSTS

Capital investment	Estimated	Actual
Processing plant	$3,898,000	$4,116,526
Pneumatic conveyors	150,000	164,388
Storage bins	687,000	551,292
Electric work	114,000	314,020
Boiler modification	179,000	178,988
Land	156,000	108,068
Engineering	275,000	376,896
Subtotal	5,459,000	5,810,178
Minor equipment and start-up	100,000	486,405
Total investment	$5,559,000	$6,296,583

The most significant cost element difference is for minor equipment and start-up expense. For purposes of accountability, all operating expenses accrued from August 30, 1975 to January 1, 1976, were arbitrarily considered start-up expenses. The decision to do so is based on year-end accounting convenience and the time necessary to learn to operate the plant and achieve a regular operating schedule after that time period. The total project estimate was exceeded by $737,583 or 13.3% which is a relatively low increase considering the newness of refuse processing technology. However, as shown in Table 30, much of this increase is start-up expense which could not accurately be predicted before the plant was constructed. When the minor equipment and start-up is removed, the difference between estimated and start-up is $351,178 or 6.4%. Of this amount, $200,020 is extra electrical work. The electrical portion of the project was expanded beyond the original estimate due to lack of appropriate electrical information from equipment suppliers, and addition of some electrical circuits. If the increased electrical work is removed, the increase in actual versus estimated project cost is only $151,158 or 2.8%.

A "rule of thumb" in many construction projects is that a 10% cost overrun is "normal" or acceptable increase. The estimated project cost was established during 1971 through 1973. Due to an unforeseen strike in the construction industry, the plant start-up date was delayed approximately 6 months and full production did not begin until January 1976. This time delay contributed to increased costs. In summary, considering the time span between when the estimate was made and when full production was achieved at the processing plant, the estimate of plant investment costs is as accurate an estimate as could have been expected.

ECONOMIC OPERATING EXPERIENCE

This section of the report presents the financial operating results of the Ames solid waste processing plant. Though the study did not begin until June 1, 1976, an effort has been made to provide results for the entire calendar year. First consideration is given to revenues, including income derived from the cash sale of recovered resources, dump fees, and noncash income obtained from the combustion of processed refuse used to generate electric power at the municipally owned electric generating plant. The second part of this section is devoted to an analysis of operating expenses.

In most instances, the term ". . . per Megagram of Refuse Received" is used as the basic common denominator of presenting comparative data. Specifically, this term refers to the amount of refuse delivered to the plant, prior to processing. The reason for selecting this term as a standard of measure is that it is the most accurately recorded measure of refuse volume and also it can be used for comparison with data from other plants irrespective of plant configuration, operating efficiencies, etc.

Cash Revenues

Cash revenue sources include the following:

1. Dump fees collected at the refuse processing plant from private citizens, commercial firms, and contract refuse haulers.

2. Sales of recovered resources extracted from the solid waste stream including metals, wood chips, and paper.

Table 31 provides a monthly breakdown of revenues for 1976. For the year, cash sales of recovered metals account for 78% of the total, followed by dump fees at 19%, wood chips at 2%, and paper at 1%. Monthly totals indicate virtually no pattern, though the summer months are moderately higher. However,

TABLE 31. PROCESSING PLANT REVENUE

	Cash revenues					Noncash revenues Revenue credit for RDF	
Month	Metals	Dump fees	Wood chips	Paper	Total	Refuse received (Mg)	Dollar value
January	$ 5,269	$ 1,216	$ 38	- --	$ 6,523	2,895	$ 29,321
February	7,357	987	264	$ 469	9,077	2,719	19,215
March	8,013	2,437	146	371	10,969	2,786	25,974
April	6,104	1,893	241	296	8,534	3,900	38,874
May	10,941	1,790	258	399	13,388	3,476	23,766
June	9,075	2,663	322	341	12,401	3,354	22,170
July	11,499	1,780	135	- --	13,414	3,194	24,124
August	9,932	2,133	249	- --	12,313	3,314	22,674
September	8,683	3,049	161	- --	11,892	3,198	34,983
October	9,937	2,930	120	- --	12,987	3,420	39,527
November	9,447	1,709	79	- --	11,789	1,739	14,735
December	4,258	1,494	229	- --	5,981	3,141	24,090
Total	$100,515	$24,081	$2,242	$1,876	$129,268	37,136	$319,453

part of the increase may be attributanle to increased public awareness and use of the waste processing plant.

Most of the recovered metal sales (75%) is derived from the sale of scrap ferrous metal extracted by the ferrous metal separation subsystem. The remaining 25% of metal sales include the sale of "white goods," i.e., refrigerators and other discarded appliances, separated from the waste stream prior to processing. Operating history indicates that scrap metal accounts for about 7% of the total waste stream, while white goods represent only about 0.75%. During the year, white goods brought about $9.07/Mg. Scrap ferrous metal is sold on a contract basis to a firm in Gary, Indiana, at prices quoted in the magazine Iron Age. Prices received trended downward during the year, from a high of about $40.82/Mg to $34.50/Mg, f.o.b. Gary, Indiana. Freight charges have approximated $15.42/Mg, resulting in a net price at Ames of $25.40 to $19.08/Mg.

Fees collected from deliveries to the processing plant are based upon the type of vehicle used. Single rear-axle vehicles are charged $0.50 per load, and multiple rear-axle vehicles are charged $1.00 per load. These rates are applicable to all deliveries, regardless of source. From the data in Table 30 there is some indication that fee collections are higher during the warmer months, apparently attributable to increased deliveries by private individuals rather than commercial trash haulers.

Noncash Revenues

This revenue item is derived from the valuation of the refuse burned as a source of fuel. It is a noncash item since the refuse is delivered to the municipally owned electric power generating plant that is adjacent to the refuse processing plant. Table 30 provides monthly revenue figures for the amount of RDF used to generate electricity.

The derivation of a value for the RDF is difficult because of several factors. First of all, the Ames plant uses a bulk-density method of measuring the amount of RDF delivered to the power plant; consequently precise measurements of actual weight are not available. Second, the combustion efficiency of the RDF versus coal is an essential element in arriving at a value, and boiler test results on this subject are not yet complete. Finally, the valuation of the RDF requires that consideration be given to the dollar value of the regular fuel (in this case, coal) that the RDF replaces. This entire matter will be given more detailed consideration during the course of the study for the year 1977. Clearly, the many factors involved indicate that RDF valuation will be unique to every operation and geographic location and that the dollar valuation presented in this report should be used with discretion for application to other locations.

Summary of Revenue Credits

The average value of the RDF for the year was \$8.60/Mg of refuse received at the processing plant, or a total of \$319,453. Cash revenues totaled \$128,714, an average of \$3.47/Mg of refuse received at the processing plant. Hence, total revenue credit was \$448,167 for 1976, or \$12.07/Mg of refuse received by the solid waste processing plant. Comparison of these actual figures with estimates developed prior to plant construction is shown below:

ACTUAL VERSUS ESTIMATED REVENUES PER MEGAGRAM
OF REFUSE PROCESSED

	Estimated	Actual
Fuel value of RDF	\$10.00	\$8.60
Recovered materials	\$3.45-\$6.30	\$3.47
Megagrams of refuse processed	49,660	37,136

The value of ferrous metal scrap is at a low point in the market place. Prior years have seen higher prices for scrap. As business activity increases, value received for recovered material may improve due to increased ferrous scrap prices. Also, the value of fuel credits per megagram of raw refuse processed will increase due to an estimated 10 to 15% annual increase in coal costs at Ames, Iowa. Also, the projected estimate of refuse volumes was made during 1971 to 1973. This estimate was made using the best data available at that time which showed refuse to be generated at the rate of 2.03 kg/capita. Although population in the City of Ames and Story County, the county that includes Ames, has increased, the amount of refuse generated per capita has decreased. City of Ames data from 1971 show that nearly 1,000 Mg of refuse per week was generated in the county. Data for 1976 show this amount to be approximately 715 Mg/week. Reasons for this significant decrease are unknown, but it conforms with decreases being experienced across the nation.

Operating Expenses

Operating expenses incurred during 1976 by the refuse processing plant are presented in Table 32. Also, presented in this table are operating cost information, megagrams of refuse received, and calculations of operating costs per megagram of refuse received.

The average operating cost per megagram received during the year, \$30.98, is considerably higher than the \$16.91 estimated before the processing plant was constructed. The critical factor here, though, is the volume of refuse processed. Indeed, had the volume of refuse reached the expected level of 49,660 Mg, the cost factor would have been \$23.00/Mg of refuse received, assuming no change in operating costs.

TABLE 32. MONTHLY OPERATING EXPENSES AND COST PER MG OF REFUSE RECEIVED AMES, IOWA, WASTE RECOVERY SYSTEM

1976 Month	Salaries[a]	All other[b]	Depreciation[c]	Interest[d]	Total	Refuse received (Mg)	Operating cost per megagram
January	$ 10,611	$ 25,011	$ 29,489	$ 23,716	$ 88,827	2,895	$30.68
February	10,961	43,188	29,489	23,716	107,354	2,719	39.48
March	12,051	40,040	29,489	23,716	105,296	2,786	37.79
April	14,409	30,195	29,489	23,716	97,809	3,900	25.08
May	10,853	59,720	29,489	23,716	123,778	3,476	35.61
June	12,144	34,541	29,489	23,716	99,890	3,354	29.78
July	13,676	1,856	29,489	23,716	68,737	3,194	21.52
August	13,571	13,451	29,489	23,716	80,227	3,314	24.21
September	14,563	24,207	29,489	23,716	91,975	3,198	28.76
October	12,160	41,717	29,489	23,716	107,082	3,420	31.31
November	10,480	30,551	29,489	23,716	94,236	1,739	54.19
December	8,194	23,915	29,489	23,716	85,314	3,141	27.16
Total	$143,673	$368,392	$353,868	$284,592	$1,150,525	37,136	$30.98

[a] Included within these figures are all employee wages paid during the year, plant management salaries, and some allocation of salaries of the Public Works Department of Ames personnel based on estimates of time devoted to the processing plant.

[b] Includes all outside services retained, supplies, repairs to equipment, uniforms, etc. Data are not available for a more specific breakdown.

[c] Departure from the accounting methods used by the City of Ames to develop total operating expense. The city makes no allowance for the estimated useful life of the operating equipment, but rather, expenses the annual principal payment on the debentures sold to finance the plant. Our opinion is that the depreciation more accurately reflects the true expense of plant amortization. Depreciation is calculated on a straight line basis.

[d] Not the actual interest paid by the City of Ames on the debenture financing, but is the annualized total interest resulting therefrom, i.e., total interest to be paid over the life of the indebtedness divided by the number of years the debt will exist. In our opinion, this more realistically reflects the interest obligation. The use of actual-interest-paid would otherwise be considerably higher during the first several years, then gradually diminish as the debentures are redeemed.

Detailed Analysis of Operating Expenses

This section of the report will include two separate parts. First, a discussion on the fixed and variable expenses of plant operations will be presented. Secondly, operating costs will be analyzed on each subsystem of the plant.

Fixed and variable expenses, for purposes of this analysis--depreciation, equipment rental, insurance premiums, plant lighting, administrative salaries, and interest charges are considered to be fixed; that is, the absolute amount of expenses will remain unchanged relative to changes in volume throughput. All other expenses and salaries are considered to be variable; that is, they can be expected to change directly proprotional to changes in throughput volume.

For the year 1976, variable expenses were $411,049 or $8.88/Mg of refuse received at the processing plant. Unfortunately, a completely detailed breakdown of the "all other" expenses is unavailable, but this expense category accounted for 87.5% of the total operating expense. Salaries and wages were $143,673, or 12.5% of the total operating expense. Based upon the amount of refuse processed, the total labor portion of the expenses resulting in $3.87/Mg of refuse processed.

An analysis of labor expenses for the period of June 1 through December 31, 1976, is presented in Table 33. For the entire year, the labor cost, both direct and indirect, was $89.58 per plant operating hour and $115.19 per actual processing hour. Obviously, the data are skewed upward because of the 2-week downtime period during the month of November after the fire.

TABLE 33. ANALYSIS OF SALARIES AND WAGE EXPENSE
(June 1 through December 31, 1976)

Month	Total salaries and wages ($)	Total operating hours	Actual processing hours	Cost per operating hour ($)	Cost per processing hour ($)
June	12,144	125.2	98.1	97.00	123.79
July	13,676	133.6	99.1	102.37	138.00
August	13,571	157.4	121.5	86.22	111.70
September	14,563	148.2	120.6	98.27	120.75
October	12,160	142.0	112.2	85.63	108.38
November	10,480	77.0	54.1	136.10	193.72
December	8,194	163.1	130.5	50.24	62.79
Total	84,788	946.5	736.1	89.58 Average	115.19 Average

An allocation of salary and wage expense by specific plant operation is presented in Table 34. In this case, expense is allocated on the basis of the average percent of labor hours during the study period to each operation. Obviously, the allocated expense includes administrative labor as well as direct. Figures of actual labor costs for each operation are unavailable, but the figures in the table provide some indication of the proportionate share of labor expense for each operation.

TABLE 34. ALLOCATION OF SALARY AND WAGE EXPENSE BY PLANT OPERATION (June 1 through December 31, 1976)

Operation	Percent of total direct labor hours	Attributable salary and wage expense ($)
General operations and shredder grates	22.2	18,823
Cleaning process area	16.7	14,160
Operating front-end loader	11.8	10,005
Tipping floor	9.6	8,140
Control room	9.1	7,716
Shredders and hammers	4.1	3,476
Secretarial and tour	4.0	3,392
Recovered metal	3.6	3,052
Janitorial	3.3	2,798
Maintenance	3.2	2,713
All other	12.4	10,513
Total	100.0	84,788

A breakdown of the all other expense categories per hour of operation is not presented in monthly tabular format because of the disparity between when an expense was incurred and when it was paid, as in the case in the City of Ames cash accounting procedure. However, using just the totals for the period between June 1 and December 31, 1976, results in an all other cost of $179.86/hr of operation, and $231.27 per actual processing hour.

In total, including both labor and all other expense, the cost per hour of operation was $269.44, and the cost per hour of actual processing was $346.56. Unfortunately, these figures cannot be compared with other facilities because of the unavailability of information.

Summary of Revenue and Expense

Table 35 presents a summary view of the financial operating results of the processing plant for the year 1976. Total operating expenses for the year were $1,150,525 and revenue credits during the period were $448,721. The quantity of refuse received at the processing plant was 37,136 Mg. For the entire year, the net operating cost per megagram received averaged $18.90 varying from a low of $9.77 in the month of July, to a high of $38.94 in November. If the November figures are not considered, because of the fire that month, the average for the year is $17.07/Mg.

TABLE 35. SUMMARY OF FINANCIAL OPERATING RESULTS

Month	Operating cost ($)	Revenue credit ($)	Refuse received (Mg)	Net operating cost per Mg of refuse ($)
January	88,827	35,844	2,895	18.30
February	107,354	28,292	2,719	29.08
March	105,296	36,943	2,786	24.53
April	97,809	47,408	3,900	12.92
May	123,778	37,154	3,476	24.92
June	99,890	34,571	3,354	19.47
July	68,737	37,538	3,194	9.77
August	80,227	34,987	3,314	13.65
September	91,975	46,875	3,198	14.10
October	107,082	52,514	3,420	15.96
November[a]	94,236	26,524	1,739	38.94
December	85,314	30,071	3,141	17.59
Total	1,150,525	448,721[b]	37,136	18.90[c]

[a] Fire in processing plant. Plant not processing for 2 weeks during cleanup and repair.

[b] Includes credits for RDF, dump fees, and recovered materials.

[c] $1,150,525 less $448,721 ÷ 37,136.

The net cost of disposal figure of $18.90 compares with an estimated range of $0.96 to $1.89 calculated in 1974 during design and projected cost studies, or 10 times higher than anticipated. To some extent, the difference can be attributed to the typically high expenses of any new facility during early periods of operation. In addition, fire damage incurred during the month of November not only ceased operations for 2 weeks, but required extensive extraordinary expenses to put the facility back into operation.

If the net disposal cost is to be reduced, it is clear that operating expenses need to be reduced while simultaneously increasing the volume of refuse throughput. For example, a 10% reduction in operating expense would reduce the net disposal cost to $15.80. If throughput volume were simultaneously increased 10%, net disposal cost could be further reduced to $14.36. Significant inroads toward reducing the net disposal cost, cannot be achieved until throughput volume is increased.

Reducing operating expenses must take into consideration the relatively high proportion of fixed charges, however. Of the $1.15 million in 1976 expenses, $739,476 are considered to be fixed, including annualized interest on the debentures, equipment rentals, administrative salaries, insurance, equipment depreciation, etc., or 56% of the total. Since nothing can be done to reduce the fixed portion, any reductions must come from the variable portion which is $411,049, including wages and variable operating expenses. As such, a 20% reduction in total operating expense ($228,360), would necessitate a 45% reduction in the variable portion, a near impossibility.

Increases in the volume of throughput can have a dramatic impact on net disposal costs, primarily because of its effect on reducing the per unit fixed cost. The Ames plant was designed for a maximum capacity of about 725 Mg/day, operating on a two-shift per day basis. This translates into about 362 Mg/day for a single shift, i.e., 8 hr/day. During the year of 1976, the Ames plant averaged only 143 Mg/day (assuming 260 working days per year). Hence, the plant was only operated at 20% of maximum capacity (at 725 Mg/day), or just 40% of capacity on a single shift basis.

Net Cost of Net Electricity Generated

During the period of the study (June 1 through December 31, 1976), records were maintained enabling a calculation of the cost of the net electricity generated by the refuse. The "net cost" figure is total costs less revenues. The "net electricity" figures are electricity generated by the RDF, less the amount of electricity consumed by the refuse processing plant. A summary of the results reveals that the value of the RDF on a per kilowatt hour basis was 3.37¢, not including the operating cost of the power generating plant. This compares to an equivalent cost of coal of about 1.40¢/kw-hr which the Ames power plant is presently paying. If the figures for the month of November are omitted because of the extraordinary occurrence of the fire, the net cost per kilowatt-hour for the period is 2.95¢. Table 36 presents the values used to calculate these figures.

TABLE 36. NET COST PER KILOWATT-HOUR OF NET ELECTRIC POWER GENERATED

	Net cost of producing RDF[a]	Net electricity generated (kw-hr)	Cost per kw-hr (in cents)
June	$ 52,983	1,490,694	4.38
July	31,199	1,629,090	1.92
August	45,240	1,559,071	2.90
September	45,100	1,778,313	2.54
October	54,568	1,858,518	2.94
November	67,712	810,135	8.36
December	55,243	1,329,996	4.15
Total	$352,045	10,445,817	3.37 Average

[a] Total operating cost, less revenue from the sale of recovered materials and credit on the fuel value of RDF.

The 3.37¢/kw-hr cost of fuel to generate electricity compares with the rule of thumb figure for operating a electric generating plant of 2.0¢/kw-hr total cost including fuel maintenance, labor, etc. Two factors should be considered, however: (a) this period of the refuse processing plant was the first full year of operation, and (b) the plant is operating at only 40% of capacity. Improvements in either of these two areas could reduce the cost of the electricity generated by RDF.

APPENDIX A - MONTHLY PROUDCTION-REFUSE PROCESSING PLANT

TABLE A-1. MONTHLY PRODUCTION - AMES, IOWA, REFUSE PROCESSING PLANT

	Weight (Mg)						
Month (1976)	Raw Refuse Processed	Glass and Grit	Rejects to Land[illegible]ill	Fe-Metal	Non Fe-Metal	Woodchips	RDF (by Difference)[a/]
January	2,894.79	28.31	136.22	183.47	0.00	67.80	2,478.99
February	2,719.42	7.24	165.83	176.50	0.00	39.45	2,330.40
March	2,785.70	16.92	278.36	157.75	1.65	29.28	2,301.74
April	3,900.30	56.06	301.42	251.01	1.26	28.96	3,261.59
May	3,476.43	14.08	274.58	236.18	0.00	23.14	2,928.45
June	3,354.01	4.20	261.10	253.43	0.00	28.43	2,806.85
July	3,193.80	56.29	210.40	244.61	0.00	25.06	2,657.44
August	3,314.41	7.67	236.65	226.65	0.00	7.69	2,835.75
September	3,197.65	4.52	237.85	215.98	0.00	12.66	2,724.96
October	3,419.85	22.01	276.41	279.01	0.00	22.06	2,820.36
November	1,739.29	0.00	134.29	133.61	0.00	0.00	1,471.39
December	3,140.88	0.00	249.99	236.49	0.08	11.16	2,643.16
Total	37,136.53	217.30	2,763.10	2,594.69	4.67	295.69	31,261.08

[a/] RDF by difference is incoming raw refuse less glass and grit, rejects, Fe-metal, Non Fe-metal, and woodchips. Therefore, the RDF by difference also includes any plant material losses.

TABLE A-2. MONTHLY PRODUCTION - AMES, IOWA, REFUSE PROCESSING PLANT

Month (1976)	Percent						
	Raw Refuse Processed	Glass and Grit	Rejects to Landfill	Fe-Metal	Non Fe-Metal	Woodchips	RDF (by Difference)[a]
January	100	0.98	4.71	6.34	0.00	2.34	85.63
February	100	0.27	6.10	6.49	0.00	1.45	85.69
March	100	0.61	9.99	5.66	0.06	1.05	82.63
April	100	1.44	7.73	6.44	0.03	0.74	83.62
May	100	0.41	7.90	6.79	0.00	0.67	84.23
June	100	0.13	7.78	7.55	0.00	0.85	83.69
July	100	1.76	6.59	7.66	0.00	0.78	83.21
August	100	0.23	7.14	6.84	0.00	0.23	85.56
September	100	0.14	7.44	6.75	0.05	0.40	85.22
October	100	0.64	8.08	8.16	0.00	0.65	82.47
November	100	0.00	7.72	7.68	0.00	0.00	84.60
December	100	0.00	7.96	7.53	0.003	0.36	84.15
Average[b]	100	0.59	7.44	6.99	0.01	0.79	84.18

[a] RDF by difference is incoming raw refuse less glass and grit, rejects, Fe-metal, Non Fe-metal, and woodchips. Therefore, the RDF by difference also includes any plant material losses.

[b] Average percent is calculated from total weight and is not an average of the individual months.

APPENDIX B - DAILY VALUES OF RDF MOISTURE CONTENT AND HEATING VALUE

TABLE B. MOISTURE AND HEATING VALUE OF DAILY SAMPLES OF RDF DISCHARGE FROM STORAGE BIN

(Samples taken by City of Ames and analysis by Ames Laboratory ERDA)

Date 1976	Moisture %	Heating Value kJ/kg As Received	 kJ/kg Moisture Free
January 2	24.60	13,891	18,423
January 5	18.36	14,544	17,815
January 6	20.42	14,931	18,762
January 7	14.89	13,607	15,998
January 8	25.22	13,007	17,394
January 9	24.63	13,105	17,388
January 10	25.49	13,479	18,090
January 12	24.83	13,921	18,519
January 14	24.29	13,637	18,012
January 15	27.73	12,874	17,814
January 16	25.00	13,656	18,208
January 17	21.24	14,103	17,906
January 19	24.45	13,735	18,180
January 20	23.31	13,975	18,222
January 21	20.06	15,538	19,437
January 22	22.44	14,175	18,276
January 23	21.00	14,898	18,858
January 24	23.02	13,823	17,957
January 25	24.16	14,070	18,552
January 26	22.94	13,649	17,712
January 27	23.10	14,424	18,756
January 28	19.77	14,996	18,691
January 29	19.89	14,947	18,656
January 30	22.07	15,540	19,941
January 31	22.13	13,493	17,328
February 1	22.95	13,591	17,639
February 2	20.65	13,723	17,295
February 3	24.55	12,853	17,036
February 4	22.68	13,514	17,478
February 5	21.11	13,816	17,514
February 6	20.99	15,289	19,350
February 7	18.87	14,440	17,798
February 9	24.26	12,484	16,482
February 10	24.72	13,340	17,720
February 11	16.76	14,168	17,020
February 12	20.38	13,500	16,956
February 13	19.02	13,791	17,029
February 14	18.60	13,388	16,448
February 15	18.63	13,877	17,054
February 16	24.45	12,728	16,847
February 17	27.93	12,260	17,012
February 19	24.59	12,314	16,329
February 20	19.99	13,837	17,295
February 21	20.77	13,840	17,468
February 23	25.06	14,019	18,707
February 24	27.89	11,797	16,360
February 25	29.85	11,530	16,436
February 26	30.80	11,374	16,436
February 27	25.00	13,030	17,374
February 29	31.35	13,786	20,082
March 1	20.35	15,880	19,937
March 2	25.60	13,047	17,536
March 3	25.21	12,093	16,169
March 4	25.98	12,651	17,091
March 5	23.43	13,342	17,424
March 8	18.20	13,898	16,990
March 9	26.92	12,111	16,573
March 10	26.51	12,239	16,655
March 11	24.81	14,130	18,793
March 13	24.17	13,093	17,266
March 17	31.76	10,939	16,030
March 18	19.15	15,826	19,575
March 23	22.19	13,309	17,105
March 25	16.99	13,575	16,353

(continued)

TABLE B. (continued)

Date 1976	Moisture %	Heating Value kJ/kg As Received	 kJ/kg Moisture Free
March 26	20.32	13,395	16,812
March 28	16.89	14,142	17,016
March 29	17.78	14,175	17,240
March 30	28.47	11,972	16,737
March 31	32.85	10,725	15,972
April 1	28.89	11,770	16,551
April 2	25.00	13,886	18,515
April 5	17.76	14,012	17,038
April 7	19.79	13,156	16,402
April 8	16.51	13,821	16,554
April 9	19.36	12,153	15,071
April 10	20.82	13,130	16,583
April 11	18.56	12,551	15,411
April 12	18.91	12,405	15,297
April 13	25.00	11,530	15,373
April 14	25.00	12,398	16,530
April 15	25.00	13,449	17,932
April 17	22.77	12,300	15,926
April 18	18.23	12,523	15,315
April 19	36 38	11,093	17,436
April 20	31.94	11,772	17,296
April 21	27.70	11,421	15,796
April 22	34.41	10,748	16,387
April 23	31.08	11,574	16,794
April 24	29.25	12,844	18,154
April 26	24.63	12,944	17,174
April 27	22.53	14,847	19,165
April 28	29.98	11,302	16,141
April 29	30.00	11,262	16,039
April 30	27.51	12,093	16,682
May 1	25.94	11,679	15,769
May 2	27.92	11,423	15,848
May 3	31.47	10,404	15,182
May 4	21.27	12,495	15,871
May 6	19.94	13,170	16,450
May 8	14.25	14,431	16,829
May 9	17.45	13,114	15,886
May 10	20.28	13,091	16,421
May 12	20.48	13,305	16,731
May 13	21.63	13,912	17,751
May 14	23.02	12,984	16,866
May 15	23.35	12,370	16,138
May 16	21.69	12,777	16,316
May 17	29.26	10,397	14,698
May 19	32.00	10,148	14,924
May 20	26.55	11,851	16,135
May 21	26.42	11,423	15,525
May 24	26.14	12,912	17,481
May 25	26.44	12,532	17,037
May 26	30.25	10,576	15,163
May 27	21.73	12,849	16,416
May 28	21.34	12,888	16,385
May 29	19.27	14,610	18,097
May 30	17.33	12,753	15,427
June 1	22.86	12,779	16,566
June 2	19.99	12,125	15,155
June 3	13.49	14,475	16,732
June 5	15.37	14,163	16,735
June 6	19.36	10,502	13,023
June 9	18.74	13,542	16,665
June 10	25.22	12,893	17,241
June 11	22.04	13,128	16,839
June 12	23.01	12,781	16,601
June 13	21.52	13,437	17,122

(continued)

TABLE B. (continued)

Date 1976	Moisture %	Heating Value kJ/kg As Received	kJ/kg Moisture Free
June 14	22.04	12,195	15,643
June 15	12.30	15,140	17,263
June 19	23.24	13,033	16,978
June 20	23.41	11,553	15,084
June 22	15.02	15,540	18,287
June 23	21.92	13,249	16,968
June 24	26.23	12,177	16,506
June 25	22.93	12,495	16,213
June 26	24.97	12,500	16,660
June 27	21.32	12,377	15,730
June 28	22.81	11,904	15,422
June 29	29.12	11,656	16,444
June 30	16.52	13,900	16,651
July 1	21.20	13,037	16,545
July 2	21.38	13.200	16,790
July 3	21.75	13,198	16,866
July 4	18.37	13,268	16,253
July 5	16.69	15,061	15,078
July 7	17.46	13,572	16,443
July 8	19.58	13,356	16,608
July 9	18.85	14,137	17,421
July 10	17.91	14,242	17,349
July 11	24.89	11,865	15,797
July 13	24.21	12,116	15,986
July 14	21.63	13,579	17,327
July 16	18.69	14,198	17,461
July 18	18.37	12,342	15,119
July 20	21.74	12,419	15,868
July 21	26.18	11,723	15,881
July 22	20.87	13,447	16,993
July 23	23.27	12,377	16,130
July 24	20.95	12,623	15,969
July 25	20.10	12,307	15,403
July 26	25.81	12,419	16,739
July 27	34.21	10,407	15,818
July 28	24.37	12,614	16,678
July 29	24.35	12,765	16,874
July 31	32.99	10,381	15,492
August 1	31.29	10,751	15,647
August 4	19.12	14,882	18,400
August 5	24.20	12,016	15,852
August 6	19.71	13,465	16,771
August 7	19.82	12,635	15,758
August 8	23.55	12,132	15,870
August 9	21.67	13,512	17,250
August 10	21.18	12,965	16,449
August 11	18.69	14,282	17,564
August 12	23.02	12,958	16,833
August 13	23.42	11,956	15,612
August 14	29.77	11,153	15,881
August 15	24.46	12,207	16,159
August 16	23.89	12,779	16,790
August 19	23.43	13,475	17,598
August 20	25.75	11,881	16,002
August 21	24.04	12,935	16,989
August 22	29.99	11,251	16,070

(continued)

TABLE B. (continued)

		Heating Value	
Date 1976	Moisture %	kJ/kg As Received	kJ/kg Moisture Free
August 23	26.93	12,414	16,989
August 25	20.88	13,388	16,922
August 26	12.45	14,742	16,839
August 27	20.16	13,137	16,454
August 28	23.00	12,607	16,373
August 29	21.21	12,774	16,213
August 31	19.41	14,217	17,641
September 1	22.84	12,923	16,749
September 2	21.33	13,475	17,128
September 3	21.03	12,139	15,372
September 4	16.61	13,926	16,700
September 5	24.15	12,398	16,345
September 6	18.12	13,668	16,692
September 7	20.20	13,426	16,824
September 8	28.94	11,932	16,792
September 10	17.50	15,210	18,436
September 11	18.30	14,296	17,498
September 12	22.89	11,128	14,431
September 13	21.57	13,784	17,575
September 15	20.14	14,230	17,819
September 16	10.31	15,866	17,689
September 17	22.02	13,654	17,509
September 18	24.93	12,437	16,567
September 19	24.19	11,996	15,823
September 20	21.66	13,516	17,253
September 21	21.26	13,607	17,281
September 22	20.86	13,216	16,700
September 23	17.56	14,407	17,476
September 24	13.84	14,386	16,697
September 25	23.05	12,670	16,465
September 26	21.88	13,135	16,814
September 27	15.73	15,205	18,043
September 28	23.18	12,284	15,990
September 29	17.97	15,261	18,604
September 30	18.07	14,528	17,732
October 1	16.25	14,163	16,911
October 2	19.03	13,714	16,937
October 3	19.71	13,551	16,878
October 4	13.28	15,731	18,140
October 5	27.65	11,974	16,550
October 7	24.09	13,451	17,720
October 8	31.23	11,604	16,874
October 9	26.73	12,125	16.549
October 10	19.56	14,007	17,413
October 11	6.88	16,970	18,224
October 12	30.49	9,678	13,924
October 13	19.66	14,198	17,672
October 16	8.10	15,584	16,958
October 17	14.76	15,598	18,299
October 18	23.50	13,014	17,012
October 19	26.37	13,477	18,303
October 20	28.02	11,607	16,125
October 21	27.52	12,307	16,980
October 22	28.47	11,470	16,035
October 23	4.31	14,177	14,816

(continued)

TABLE B. (continued)

		Heating Value	
Date 1976	Moisture %	kJ/kg As Received	kJ/kg Moisture Free
October 24	19.65	13,754	17,117
October 25	19.83	14,598	18,209
October 26	27.14	12,079	16,578
October 27	16.87	14,842	17,854
October 28	25.32	11,844	15,860
October 29	23.32	12,646	16,493
October 30	17.39	13,568	16,424
October 31	27.96	10,758	14,929
November 2	17.85	15,500	18,868
November 3	18.60	14,130	17,359
November 4	26.40	14,896	20,239
November 5	26.62	14,489	19,745
November 6	23.63	13,193	17,275
November 7	29.19	13,963	19,719
November 23	11.72	16,645	18,855
November 24	16.04	14,493	17,262
November 25	12.68	15,912	18,223
November 26	16.97	13,528	16,293
November 27	25.38	13,407	17,967
November 29	20.25	13,775	17,272
November 30	24.04	14,077	18,532
December 1	18.84	12,584	15,505
December 2	26.56	11,642	15,852
December 3	24.35	13,091	17,304
December 4	23.40	13,040	17,023
December 5	22.63	11,856	15,323
December 6	17.77	15,279	18,581
December 8	12.05	16,052	18,251
December 9	26.24	12,677	17,186
December 10	21.35	12,947	16,461
December 11	26.35	11,770	15,980
December 12	23.97	12,721	16,731
December 13	17.97	15,361	18,726
December 14	24.12	13,093	17,255
December 15	12.97	14,589	16,763
December 16	22.40	13,312	17,154
December 19	25.33	10,962	14,681
December 20	16.50	16,301	19,522
December 22	17.25	14,603	17,647
December 23	21.93	13,637	17,468
December 24	18.56	11,302	13,878
December 25	25.32	11,239	15,050
December 27	13.40	14,475	16,715
December 28	9.78	15,712	17,415
December 29	21.95	12,860	16,477
December 30	16.78	14,891	17,894
December 31	20.40	14,019	17,612
Mean $\bar{x}$	22.23	13,188	16,967
Number of samples, n	286	286	286
Standard deviation, S_x	4.864	1,297.2	1,141.0
Coefficient of variation, CV %[a]	21.88	9.84	6.72

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[a] CV is the standard deviation expressed as a percent of the mean.

APPENDIX C - TABULATION OF INFORMATION ON EQUIPMENT AND FACILITIES EVALUATION

GLOSSARY OF TERMS--USED IN DAILY ACTIVITY LOG-TABLE C-1

RDF	Refuse-derived fuel.
(C-1); (C-2), etc.	The letter and number in the parentheses refer to the designation on the flow diagram.
High-Pressure Limit Switch	The pneumatic conveying line from the processing plant to the storage bin is fitted with a pressure sensor adjacent to the blower. If a clog of RDF in the line starts to form there will be an increase in the pneumatic conveying line pressure. This increase in line pressure is detected by the sensor which activates a switch to stop all conveyors. This prevents the rotary air lock from feeding more RDF into the pneumatic line which could cause a major plug in the line. The conveyors cannot restart until the conveying line has cleared itself and the pressure is lowered. Set point on the sensor is approximately 17.2 kPa (2.5 psi).
Change Trailers	Fe-metal is conveyed to bulk material trailers. When a trailer is full, the plant is shut down to remove the full trailer and replace it with an empty trailer. Glass, non-Fe-metal, and reject material are stored in holding bins, and no plant downtime is necessary to load out these materials.

TABLE C-1a. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF JUNE 1976

Day (June 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
1	Tuesday	17.0	8:00 a.m.	Plant start-up.
				ADS drag conveyor drive motor burned out and taken to shop for rewinding. This is first time this has happened.
			3:00 p.m.	ADS motor reinstalled and processing started.
			20 min	Changed trailers.
			1:00 a.m.	Plant shutdown.
2	Wednesday	9.0	8:00 a.m.	Plant start-up.
			8:00-9:30 a.m.	Bearing temperature sensor on shredder 1 indicated hot temperature. Plant shutdown to check out bearing and sensor.
			20 min	Changed trailers.
			5:00 p.m.	Plant shutdown.
3	Thursday	11.0	7:00 a.m.	Plant start-up.
			6:00 p.m.	Plant shutdown.
4	Friday	11.0	7:00 a.m.	Plant start-up.
			6:00 p.m.	Plant shutdown.
7	Monday	9.0	8:00 a.m.	Plant start-up.
			5:00 p.m.	Plant shutdown.
8	Tuesday	8.5	8:00 a.m.	Plant start-up.
			20 min	Changed trailers
			20 min	Front-end loader used to load scrap metal in dump truck.
			3:00-4:00 p.m.	Pneumatic conveyor rotary air lock feeder plugged.
			4:30 p.m.	Plant shutdown.
9	Wednesday	8.5	8:00 a.m.	Plant start-up. Not enough raw refuse accumulated to start processing.
			10:20 a.m.	Processing commenced.
			20 min	Changed trailers.
			1:50-2:20 p.m.	Vibrating conveyor (C-2) receiving shredder 1 discharge plugged.
			4:30 p.m.	Plant shutdown.
10	Thursday	8.5	8:00 a.m.	Plant start-up.
			4:30 p.m.	Plant shutdown.

(continued)

TABLE C-1a. (continued)

Day (June 1976)	Day of Week	Processing Day Hours[a/]	Clock Time	Description
11	Friday	15.5	8:00 a.m.	Plant start-up.
			8:25 a.m.	Fire in ADS fan motor. Processing stopped.
			4:30 p.m.	Processing resumed.
			10 min	Feed hopper to belt conveyor (C-3) from shredder 1 to 2 plugged.
			5 min	Pneumatic conveyor high-pressure limit switch activated three times.
			7:30-7:50 p.m.	Changed trailers.
			11:30 p.m.	Plant shutdown.
14	Monday	0	8:00 a.m.- 4:00 p.m.	Decision not to process refuse to allow Atlas bin to be emptied and cleaned. Lubrication and maintenance check of plant.
15	Tuesday	8.7	6:00 a.m.	Plant start-up.
			2:40 p.m.	ADS drag conveyor drive motor burned out and taken to shop for rewinding. Second time for this occurrence. Plant shutdown for balance of day.
16	Wednesday	0		No operation because waiting for ADS motor from shop. Atlas bin shutdown due to loose rollers on sweep conveyor.
17	Thursday	7.5	5:00 p.m.	ADS drag conveyor motor repaired.
			7:30 p.m.	Plant start-up.
			3:00 a.m.	Seven flights came loose from ADS conveyor and drag conveyor motor burned out for the third time. Believe motor burnout due to motor overload thermal relay not tripping circuit breaker. Plant shutdown. Motor sent to shop for repair.
18	Friday	0		No processing. Repair of ADS drag conveyor and motor.
19	Saturday	3.9	1:35 p.m.	Plant start-up. Processing backlog of refuse.
			5:30 p.m.	Plant shutdown.
21	Monday	1.7	10:30 a.m.	Plant start-up.
			12:10 p.m.	Screw conveyor feeding pneumatic conveyor system plugged and drive motor burned out. Motor sent to shop to be rewound. Plant shutdown. Raw refuse trucks routed to landfill.

(continued)

TABLE C-1a. (continued)

Day (June 1976)	Day of Week	Processing Day Hours a/	Clock Time	Description
22	Tuesday	19.7	10:10 a.m.	Screw conveyor motor repaired and reinstalled.
			11:00 a.m.	Plant start-up.
			1:15 p.m.	Stopped processing due to hole in Atlas bin.
			2:00 p.m.	Commenced processing again.
			2:20-2:25 p.m.	Belt conveyor (C-7) receiving ADS heavies plugged.
			3:05-3:10 p.m.	Vibrating conveyor (C-2) receiving shredder 1 discharge plugged due to light paper.
			3:30-3:55 p.m.	ADS feed vibrating conveyor plugged.
			5:20-5:25 p.m.	Conveyor (C-7) plugged due to wet material.
			10 min	Metal trailer changed.
			5:40-5:45 p.m.	Conveyor (C-7) plugged due to wet material.
			6:20-7:20 p.m.	Cleaned out ADS return air duct.
			8:05-8:15 p.m.	Belt conveyor (C-6) feeding ADS motor circuit breaker tripped due to large metal piece jammed in tail pulley.
			11:35-11:45 p.m.	Changed trailers.
			2:10-3:01 a.m.	Belt conveyor (C-12) for Fe-metal jammed due to large wire causing belt to be thrown off head pulley.
			3:15-3:20 a.m.	Conveyor belt (C-11) to Fe-metal trailer plugged.
			5:10 a.m.	Plant shutdown.
23	Wednesday	8.0	12:00 p.m.	Plant start-up.
			12:30-12:35 p.m.	Raw refuse in-feed conveyor (C-1) jammed.
			12:45-12:50 p.m.	Belt conveyor (C-7) receiving ADS heavies plugged.
			1:20-1:30 p.m.	Conveyor (C-7) jammed.
			1:50-2:00 p.m.	Conveyor (C-1) jammed.
			2:25-2:35 p.m.	Conveyor (C-7) plugged.
			2:50-3:00 p.m.	Conveyor (C-7) plugged.
			3:20-3:45 p.m.	Typewriter tape cleaned from screen on ADS air inlet. This plugged screen had reduced the amount of air pulled into the ADS system, which caused part of the light fraction (RDF) to fall out with the heavies. This is the reason conveyor (C-7) was plugging so often.
			4:00 p.m.	Plant shutdown.
24	Thursday	4.3	12:10 p.m.	Plant start-up.
			12:15-12:35 p.m.	Fe-metal belt conveyor (C-11) plugged.
			1:10-1:15 p.m.	Raw refuse in-feed conveyor (C-1) jammed.
			1:50-1:55 p.m.	Conveyor (C-1) stopped to run process empty to clear ADS drag conveyor.
			2:50-3:05 p.m.	Changed trailers.
			4:30 p.m.	Plant shutdown.

(continued)

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TABLE C-1a. (continued)

Day (June 1976)	Day of Week	Processing Day Hours[a]	Clock Time	Description
25	Friday			Prior to start-up, general cleanup, maintenance on aluminum separation systems, and cleaned and aligned screw conveyor motor.
		1.8	12:10 p.m.	Plant start-up.
			12:15-12:50 p.m.	AHS heavies belt conveyor (C-15) jammed.
			1:40-1:45 p.m.	Emergency stop button in-plant activated by pile-up of refuse.
			2:10-2:20 p.m.	Raw refuse in-feed conveyor (C-1) jammed.
			3:05-3:20 p.m.	Changed trailers.
			4:00 p.m.	Plant shutdown at request of power plant due to loose roller on Atlas bin sweep conveyor.
				Plumbing contractor changed galvanized water pipe to copper because of hardness of water.
26	Saturday	0		No processing. General maintenance and all motors cleaned. Five employees in work crew. 172 private automobiles delivered raw refuse.
28	Monday		5 min	Prior to start-up. Pumped up low tire on end loader.
		9.0	8:30 a.m.	Plant start-up.
			30 min	Magnetic belt down seven times.
			25 min	Raw refuse in-feed conveyor (C-1) jammed five times.
			10:00-11:00 a.m.	Repaired flight on conveyor (C-1) which had sheared two bolts.
			11:10-11:15 a.m.	Fueled front-end loader.
			1:50-2:30 p.m.	Atlas bin had plugged drag conveyor.
			3:15-4:15 p.m.	Changed trailers and fueled front-end loader (loader had run out of fuel).
			5:30 p.m.	Plant shutdown.
29	Tuesday	8.5	8:30 a.m.	Plant start-up.
			9:00-9:10 a.m.	Replaced thread on raw refuse in-feed conveyor (C-1) bearing.
			5 min	Shutdown due to pneumatic conveyor high-pressure limit switch.
			9:40-9:45 a.m.	Conveyor (C-1) jammed.
			11:00-12:30 p.m.	Repaired conveyor (C-1) due to bent flight caused by sheared bolt and repaired front-end loader hydraulic system.
			20 min	Wood chipper jammed.
			12:30 p.m.	Commenced processing again.
			5 min	Conveyor (C-1) jammed three times.
			20 min	Pneumatic conveyor high-pressure limit switch activated 15 times.
			5:00 p.m.	Plant shutdown.
30	Wednesday			Prior to start-up replaced both existing metal shredder curtains with rubber curtains. Constant impact of refuse against metal curtains caused them to open occasionally. Felt that rubber would be a better curtain material.
		4.5	11:45 a.m.	Plant start-up.
			11:55-12:00 p.m.	Hopper feeding belt conveyor (C-3) from shredders 1 to 2 plugged.
			20 min	Pneumatic conveyor high-pressure limit switch activated.
			15 min	Raw refuse in-feed conveyor (C-1) jammed.
			4:15 p.m.	Plant shutdown due to broken flight on AHS drag conveyor and broken "A" frame at bottom of conveyor.

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a/ Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1b. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF JULY 1976

Day (July 1976)	Day of Week	Processing Day-Hours a/	Clock Time	Description
1	Thursday			Prior to start-up two workmen aligned chain on ADS drag conveyor
		7.9	12:35 p.m.	Plant start-up.
			1:35-2:15 p.m.	Changed trailers.
			5:40-6:00 p.m.	Changed trailers.
			15 min	Raw refuse in-feed conveyor (C-1) jammed three times.
			10 min	Pneumatic conveyor high-pressure limit switch activated twice.
			8:30 p.m.	Plant shutdown.
2	Friday	9.9	6:35 a.m.	Plant start-up.
			20 min	Raw refuse in-feed conveyor (C-1) jammed four times.
			7:35-7:60 a.m.	ADS feeder motor overload relay activated.
			8:25 a.m.	Plant shutdown due to lack of raw refuse and metal and reject trailers full.
			10 min	Loaded scrap metal into dump truck with front-end loader.
			10:30 a.m.	Resumed processing.
			10 min	Conveyor (C-1) jammed three times.
			10:50-11:15 a.m.	Repaired two broken bolts on conveyor (C-1) and belt conveyor (C-6) from shredders 1 to 2 also plugged
			12:25-12:30 a.m.	ADS feeder jammed.
			1:05-1:20 p.m.	Shutdown to repair ADS surge bin.
			1:45-1:50 p.m.	Fe-metal belt conveyor (C-13) plugged.
			2:00-2:05 p.m.	Conveyor (C-1) jammed.
			2:35-3:00 p.m.	Reverse air trap on duct to ADS fan plugged.
			3:30-3:35 p.m.	Vibrating conveyor (C-2) receiving refuse from shredder 1 plugged.
			4:30 p.m.	Plant shutdown.
5	Monday	0		Holiday - Independence Day.
6	Tuesday	7.8	8:45 a.m.	Plant start-up.
			8:55-9:05 a.m.	Stopped processing at request of power plant.
			9:10-9:20 a.m.	Repaired bent flight on raw refuse in-feed conveyor (C-1).
			12:45-12:55 p.m.	Wire caused pluggage of magnetic belt separator.
			1:50-2:05 p.m.	Changed trailers.
			2:15-2:20 p.m.	Magnetic belt separator plugged.
			4:30 p.m.	Plant shutdown.
7	Wednesday			Prior to plant start-up, replaced door to raw refuse in-feed conveyor (C-1), welded shut hole in pneumatic conveyor pipeline at processing plant and put temporary patch on hole in pneumatic conveyor pipeline at Atlas bin, and performed clean-up, lubrication of equipment and general maintenance.
		3.7	11:35 a.m.	Plant start-up
			12:05-12:15 p.m.	Magnetic belt separator plugged.
			12:55-1:15 p.m.	Changed metal trailer.
			15 min	Conveyor (C-1) jammed six times.
			4:15 p.m.	Plant shutdown.

(continued)

TABLE C-1b. (continued)

Day (July 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
8	Thursday	4.7	11:40 a.m.	Plant start-up.
			1:10-1:15 p.m.	Pneumatic conveyor high-pressure limit switch activated four times.
			1:25-1:55 p.m.	Changed trailers.
			4:20 p.m.	Plant shutdown.
9	Friday	5.6	10:45 a.m.	Plant start-up.
			11:05-11:10 a.m.	ADS feed belt conveyor (C-6) motor overload relay activates.
			11:45-12:55 p.m.	Repaired raw refuse in-feed conveyor (C-1) and broken drive pin on conveyor (C-1).
			1:05-1:15 p.m.	Cleaned screen on ADS vibrating feeder.
			3:15-4:20 p.m.	Changed trailers. Delay due to plant personnel working on paper baler construction.
			15 min	Conveyor (C-1) jammed four times.
			4:20 p.m.	Plant shutdown.
12	Monday	7.3	8:00 a.m.	Plant start-up.
			8:10-8:20 a.m.	Feed hopper to belt conveyor (C-3) from shredders 1 to 2 plugged.
			8:25-9:15 a.m.	ADS feeder plugged.
			9:15-11:45 a.m.	Repaired hole in pneumatic conveyor line.
			1:45-1:50 p.m.	ADS feeder plugged.
			5 min	In-feed conveyor (C-1) jammed.
			3:15 p.m.	Explosion in Shredder 1. Plant shutdown. Flames passed along belt conveyor (C-3) to shredder 2 causing second explosion in shredder 2. Flames continued to ADS drag conveyor. Plant employees immediately fought fire with hoses. Ames Fire Department arrived in approximately 5 min. Raw refuse delivery trucks routed to landfill.
			5:30 p.m.	Fire declared dead. All raw refuse pulled out of in-feed conveyor (C-1) and thoroughly soaked with water and later hauled to landfill. Work continued to clean up area and unclog refuse filled plant drains. No damage found.
			10:15 p.m.	Plant equipment started and checked out. All worked well.
			11:00 p.m.	All personnel left plant except for one man to maintain fire watch with pump.
				Raw refuse delivery trucks routed to landfill from 3:15 to 4:00 p.m.
13	Tuesday	8.0	10:10 a.m.	Plant start-up.
			12:10-12:25 p.m.	Shear pin broke in raw refuse in-feed conveyor (C-1).
			1:10-1:13 p.m.	Pneumatic conveyor high-pressure limit switch activated.
			20 min	Conveyor (C-1) jammed 17 times due to brush in raw refuse.
			3:00-3:40 p.m.	Change trailers.
			3:40-3:55 p.m.	Realigned magnetic belt relay.
			4:25-5:00 p.m.	ADS feeder motor overload activated.
			6:10 p.m.	Plant shutdown.

(continued)

TABLE C-1b. (continued)

Day (July 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
14	Wednesday	6.3	10:00 a.m.	Plant start-up.
			11:30-12:10 p.m.	Repaired two broken bolts on raw refuse in-feed conveyor (C-1); lost two bolts.
			12:55-11:10 p.m.	Belt conveyor (C-6) to ADS jammed due to steel in refuse.
			1:10-1:25 p.m.	Stopped operation to unload freezer from delivery vehicle.
			3:55-4:10 p.m.	Vibrating conveyor (C-2) receiving refuse from shredder 1 plugged.
			4:20 p.m.	Plant shutdown.
			(Records analyzed show front-end loader consumes an average 2.5 gal. of diesel fuel per hr)	
15	Thursday	6.9	9:30 a.m.	Plant start-up.
			9:55-10:20 a.m.	Vibrating conveyor (C-2) receiving refuse from shredder 1 plugged due to large pieces of cardboard.
			5 min	Pneumatic conveyor high-pressure limit switch activated.
			20 min	Raw refuse in-feed conveyor (C-1) jammed eight times.
			2:45-3:10 p.m.	Change trailers.
			3:15-3:45 p.m.	Belt conveyor (C-3) from shredder 1 to shredder 2 plugged at shredder 2.
			4:25 p.m.	Plant shutdown.
16	Friday	6.8	9:50 a.m.	Plant start-up.
			10:15-10:27 a.m.	Refuel front-end loader.
			10:34-10:39 a.m.	Magnetic belt separator plugged.
			10:46-10:58 a.m.	Cleared wire caught in Fe-metal system belt conveyor (C-11 and C-12).
			11:46-11:49 a.m.	Cleared wire caught in conveyor (C-12).
			2:20-3:15 p.m.	Change trailers.
			3:50 p.m.	ADS vibrating feeder plugged.
			15 min	Raw refuse in-feed conveyor (C-1) jammed seven times.
			4:35 p.m.	Plant shutdown.
19	Monday	8.4	8:20 a.m.	Plant start-up.
			8:27-8:41 a.m.	Fe-metal belt conveyor (C-13) plugged.
			9:00 a.m.	ADS heavies belt conveyor (C-7) plugged.
			9:18-12:55 p.m.	Shutdown to check shredder 1 bearing.
			2:13-2:46 p.m.	Shutdown to check equipment.
			3:00 p.m.	Fe-metal belt conveyor (C-13) plugged.
			10 min	In-feed conveyor (C-1) plugged five times.
			3:40-3:45 p.m.	ADS heavies felt conveyor (C-7) plugged.
			4:45 p.m.	Plant shutdown.

(continued)

TABLE C-1b. (continued)

Day (July 1976)	Day of Week	Processing Day-Hours[a/]	Clock Time	Description
20	Tuesday			Prior to plant start-up welded repairs on front end loader bucket, repaired handrails on raw refuse in-feed conveyor (C-1), aluminum separation system belt conveyor (C-20), and leaks in water system.
		9.0	9:55 a.m.	Plant start-up.
			10:55-11:04 a.m.	ADS drag conveyor motor overload relay activated.
			11:55-12:00 p.m.	Magnetic belt separator stalled.
			12:10-12:15 p.m.	Stopped operations to remove gasoline can from raw refuse.
			1:55 p.m.	Loaded dump truck.
			2:48-5:10 p.m.	Repair ADS drag conveyor. Seven flights lost.
			6:20-6:25 p.m.	Pneumatic conveyor high-pressure limit switch activated.
			6:55 p.m.	Plant shutdown.
21	Wednesday	8.8	6:55 a.m.	Plant start-up.
			9:25-9:30 a.m.	Fe-metal belt conveyor (C-13) plugged tail pulley.
			9:40-10:02 a.m.	Repaired loose bolt in front-end loader bucket.
			10:17-12:47 p.m.	Bearing manufacturer checking bearings.
			1:45-2:07 p.m.	ADS drag conveyor motor overload relay activated. ADS feeder plugged.
			3:00-3:20 p.m.	Changed trailers.
			4:18 p.m.	Plant shutdown.
22	Thursday	6.7	9:40 a.m.	Plant start-up.
			17 min	Pneumatic conveyor high-pressure limit switch activated six times.
			1:40-2:49 p.m.	Check out equipment.
			3:00-3:45 p.m.	ADS drag conveyor plugged.
			4:23 p.m.	Plant shutdown.
23	Friday	4.3		Plant operated with no difficulty. Start and stop times not recorded. Processing time taken from shredder running hours meter.
26	Monday	8.0	7:10 a.m.	Plant start-up.
			7:10-7:20 a.m.	Conveyor belt (C-3) shredder 1 to 2 had difficulty in starting.
			7:30-7:32 a.m.	Magnetic belt separator plugged.
			8:00-10:00 a.m.	Changed trailers. Repair hydraulic hose on front-end loader.
			5 min	Magnetic belt separator plugged three times.
			7 min	Raw refuse in-feed conveyor (C-1) jammed three times.
			23 min	Pneumatic conveyor high-pressure limit switch activated 17 times.
			3:15-3:40 p.m.	Changed trailers.
			4:10 p.m.	Plant shutdown.

(continued)

TABLE C-1b. (continued)

Day (July 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
27	Tuesday	12.8	10:10 a.m.	Plant start-up.
			4 min	Pneumatic conveyor high-pressure limit switch activated twice.
			11:00 a.m.- 3:00 p.m.	Shutdown plant to work on Atlas bin. Sweep conveyor loose and mistracking.
			5 min	Raw refuse in-feed conveyor (C-1) jammed twice.
			5:29-6:55 p.m.	Shutdown plant for dinner.
			6:55-7:05 p.m.	Fe-metal rejects belt conveyor (C-1) jammed at tail pulley.
			10 min	Conveyor (C-1) jammed five times.
			15 min	Pneumatic conveyor high-pressure limit switch activated seven times.
			8:30-9:00 p.m.	Changed trailers.
			9:00-9:15 p.m.	ADS feeder plugged.
			5 min	Fe-metal belt conveyor (C-13) plugged.
			11:00 p.m.	Plant shutdown.
28	Wednesday	4.3	11:47 a.m.	Plant start-up.
			9 min	Raw refuse in-feed conveyor (C-1) jammed five times.
			12 min	Pneumatic conveyor high-pressure limit switch activated eight times.
			3:07 p.m.	Plant shutdown.
				ADS inspected by manufacturer. Discovered that the drag conveyor constructed wrong. The return sprocket and belt tension adjustment sprocket had been reversed, allowing shredder refuse to pack in the feeder and force the chain flights out of alignment. This misalignment overstressed the flights and caused their eventual breakage. Replacement with the correct sprockets by the manufacturer was scheduled for Saturday, July 31, 1976.
29	Thursday	7.9	8:38 a.m.	Plant start-up.
			9:05-9:20 a.m.	ADS vibrating feeder plugged.
			9:43-9:50 a.m.	Magnetic belt separator plugged and pneumatic conveyor high-pressure limit switch activated.
			10:15-10:20 a.m.	Pneumatic conveyor high-pressure limit switch activated.
			11:20-11:30 a.m.	Belt conveyor (C-6) to ADS stalled.
			11:47 a.m.- 2:20 p.m.	Plant shutdown for lunch and repair of fire protection system piping.
			2:30-2:35 p.m.	Fe-metal belt conveyor (C-13) plugged.
			2:50-3:00 p.m.	ADS heavies bucket elevator (E-1) plugged.
			3:15-3:30 p.m.	Pneumatic conveyor high-pressure limit switch activated.
			21 min	Raw refuse in-feed conveyor jammed nine times.
			15 min	Pneumatic conveyor high-pressure limit switch activated.
			3:40-3:45 p.m.	ADS heavies belt conveyor (C-7) plugged.
			3:55-4:00 p.m.	Belt conveyor (C-6) to ADS stalled.
			4:30 p.m.	Plant shutdown.
30	Friday	18.3	8:20 a.m.	Plant start-up
			8:50-9:05 a.m.	ADS drag conveyor plugged.
			10:30 a.m.	Plugged shredder 2. Cleaned out plug and changed hammers. Changed trailers. Plant shutdown.
			9:07 p.m.	Plant start-up.
			2:35 a.m.	Plant shutdown on Saturday, July 31.

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[a] Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1c. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF AUGUST 1976

Day (August 1976)	Day of Week	Processing Day-Hours[a/]	Clock Time	Description
2	Monday	0.5	9:25 a.m.	Plant start-up.
			9:40-9:42 a.m.	ADS scalping roll motor overload relay activated.
			9:45 a.m.	Plant shutdown. ADS drag conveyor became misaligned and nine flights broken. Shutdown for the day to repair drag conveyor. Also, maintenance performed on Atlas bin sweep conveyor.
3	Tuesday	2.1	7:10 a.m.	Plant start-up.
			8:55-9:00 a.m.	Magnetic belt separator plugged.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed six times. Time not recorded.
			9:15 a.m.	Plant shutdown.
4	Wednesday	11.8	6:10 a.m.	Plant start-up.
			6:55-7:00 a.m.	Raw refuse in-feed conveyor (C-1) motor overload relay activated.
			7:30-7:50 a.m.	Fe-metal belt conveyor (C-10) plugged with paper.
			9:30-9:40 a.m.	Magnetic belt separator stopped.
			10:40-11:05 a.m.	Changed trailers.
			12:40-12:45 p.m.	Belt conveyor (C-6) to ADS tail pulley jammed.
			4:05-4:30 p.m.	Changed trailers.
			N.R.	Pneumatic conveyor high-pressure limit switch activated eight times.
			N.R.	Conveyor (C-1) jammed 42 times.
			5:55 p.m.	Plant shutdown.
			N.R	Time not recorded.
5	Thursday	11.3	8:20 a.m.	Plant start-up.
			9:20-9:40 a.m.	Fire in primary metals trap.
			11:20-12:00 p.m.	Plant shutdown.
			12:25-12:27 p.m.	Magnetic belt separator stopped.
			12:57-1:00 p.m.	Magnetic belt separator stopped.
			1:43-1:45 p.m.	Magnetic belt separator stopped.
			1:53-3:05 p.m.	Belt conveyor (C-6) to ADS motor overload relay activated and tail pulley jammed.
			3:10-4:50 p.m.	Changed trailers. Removed bed spring wound around front-end loader axles.
			5:45-5:50 p.m.	Magnetic belt separator stopped.
			6:50-6:55 p.m.	Magnetic belt separator stopped.
			N.R.	Pneumatic conveyor high-pressure limit switch activated four times. Time not recorded.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed nine times. Time not recorded.
			7:40 p.m.	Plant shutdown.

(continued)

TABLE C-1c. (continued)

Day (August 1976)	Day of Week	Processing Day-Hours^a/	Clock Time	Description
6	Friday	12.6	6:10 a.m.	Plant start-up.
			6:40-6:45 a.m.	Magnetic belt separator stopped.
			7:10-7:45 a.m.	Raw refuse in-feed conveyor (C-1) motor overload relay activated.
			7:20-7:25 a.m.	Magnetic belt separator stopped.
			7:45-7:50 a.m.	Magnetic belt separator stopped.
			8:50-11:30 a.m.	Conveyor (C-1) motor overload relay activated. Replaced loose bolts in conveyor (C-1). Repaired hole in magnetic belt separator. Loaded scrap metal truck.
			12:30-1:20 p.m.	Changed trailers.
			1:20-1:30 p.m.	Added oil to front-end loader.
			N.R.	Conveyor (C-1) jammed 28 times. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated three times. Time not recorded.
			6:45 p.m.	Plant shut down.
7	Saturday	-		Worked 3.5 hours changing some of the hammers in the first stage shredder.
9	Monday	7.6	8:30 a.m.	Plant start-up.
			10:00-10:30 a.m.	Changed trailers.
			1:00-1:45 p.m.	Shut down at request of power plant.
			N.R.	Pneumatic conveyor high-pressure limit switch activated five times. Time not recorded.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed 10 times. Time not recorded.
			4:05 p.m.	Plant shutdown.
10	Tuesday	6.5	7:05 a.m.	Plant start-up.
			7:25-7:55 a.m.	Changed trailers.
			11:40-12:05 p.m.	Refueled front-end loader.
			1:05-1:20 p.m.	Fe-metal belt conveyor (C-12) jammed.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed eight times.
			1:35 p.m.	Plant shutdown.
				Before plant start-up installed a screen around the second stage shredder motor. Also, changed some of the hammers in the first stage shredder. This was a lengthy job because the hammers and the shaft seemed to be rusted together. Hammer change required 3.5 hr Saturday and 4 hr Wednesday for 7.5 hr total.
11	Wednesday	4.2	1:35 p.m.	Plant start-up.
			1:45-1:55 p.m.	ADS heavies belt conveyor (C-14) jammed.
			2:30-2:55 p.m.	Changed trailers.
			4:45-5:00 p.m.	Replaced broken shear pin on raw refuse in-feed conveyor (C-1).
			5:00-5:25 p.m.	Removed wire wound around front-end loader drive shaft.
			5:25-5:45 p.m.	Bent flight on ADS drag conveyor.
			5:45 p.m.	Plant shutdown.

(continued)

TABLE C-1c. (continued)

Day (August 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
12	Thursday	10.3	6:10 a.m.	Plant start-up.
			7:40-7:50 a.m.	Straightened bent flight on raw refuse in-feed conveyor (C-1).
			9:25-9:50 a.m.	Changed trailers.
			2:20-2:25 p.m.	Magnetic belt separator stopped.
			4:00-4:10 p.m.	Refueled front-end loader.
			30 min	Conveyor (C-1) jammed 24 times.
			5 min	Pneumatic conveyor high-pressure limit switch activated seven times.
			4:25 p.m.	Plant shutdown.
13	Friday	6.3	9:10 a.m.	Plant start-up.
			9:30-9:35 a.m.	Fe-metal belt conveyor (C-11) jammed.
			9:40-9:45 a.m.	ADS heavies belt conveyor (C-7) plugged.
			11:45-12:55 a.m.	Belt conveyor (C-6) to ADS jammed.
			10 min	Raw refuse in-feed conveyor (C-1) jammed seven times.
			15 min	Pneumatic conveyor high-pressure limit switch activated seven times.
			4:30 p.m.	Plant shutdown.
16	Monday	7.7	8:20 a.m.	Plant start-up.
			3 min	Pneumatic conveyor high-pressure limit switch activated once.
			9:00-9:25 a.m.	Changed trailers.
			10:20-11:05 a.m.	Belt conveyor (C-3) shredders 1 to 2 jammed due to piece of wood stuck in head pulley.
			12:30-12:35 p.m.	Conveyor (C-3) plugged.
			1:30-1:35 p.m.	Conveyor (C-3) plugged.
			2:50-2:55 p.m.	ADS heavies belt conveyor (C-14) jammed.
			3:05-3:20 p.m.	Conveyor (C-3) plugged.
			3:25-3:35 p.m.	Conveyor (C-3) plugged
			20 min	Raw refuse in-feed conveyor (C-1) jammed 14 times.
			4:00 p.m.	Plant shutdown.
17	Tuesday			Before plant start-up changed wear back elbow on pneumatic conveying line at Atlas bin cyclone. Also, worked on shredder 2 curtain in in-feed throat because believe this to be cause of conveyor (C-3) pluggage (refuse backing up on conveyor).
		7.7	11:20 a.m.	Plant start-up.
			11:20-12:20 p.m.	Cleaned ADS surge bin of wet material.
			1:05-2:05 p.m.	Changed trailer. Delivery blocked by crane.
			6:35-6:40 p.m.	Raw refuse in-feed conveyor (C-1) motor overload relay activated.
			20 min	Conveyor (C-1) jammed 12 times.
			N.R.	Pneumatic conveyor high-pressure limit switch activated once. Time not recorded.
			7:00 p.m.	Plant shutdown.
18	Wednesday	0		No processing. Changed chain and flights in ADS drag conveyor. Cleaned plant. Drag conveyor work completed by 3:00 p.m. and ran equipment check. Welded angles in primary shredder until 1:00 a.m.

(continued)

TABLE C-1c. (continued)

Day (August 1976)	Day of Week	Processing Day-Hours[a]	Clock time	Description
19	Thursday	10.2	7:20 a.m.	Plant start-up.
			7:25-7:40 a.m.	Vibrating conveyor (C-2) receiving shredder 1 discharge plugged.
			9:05-9:15 a.m.	Vibrating conveyor (C-2) plugged.
			1:20-1:55 p.m.	Changed trailers.
			2:45-2:50 p.m.	Belt conveyor (C-3) shredders 1 to 2 plugged.
			3:05-3:20 p.m.	Belt conveyor (C-3) plugged.
			3 min	Raw refuse in-feed conveyor (C-1) jammed once.
			15 min	Pneumatic conveyor high-pressure limit switch activated five times.
			4:10-4:25 p.m.	Belt ripped on magnetic belt separator. Shut off shredder 1.
			5:30 p.m.	Plant shutdown.
20	Friday	3.8	8:45 a.m.	Plant start-up.
			8:55-9:05 a.m.	ADS vibrating feeder plugged.
			10:20-10:25 a.m.	Belt conveyor (C-3) shredders 1 to 2 jammed.
			11:05-11:30 a.m.	Sweep conveyor in Atlas bin broken.
			11:45-12:05 p.m.	Belt conveyor (C-3) plugged.
			12:10-12:25 p.m.	Belt conveyor (C-3) plugged.
			12:30 p.m.	Plant shutdown.
				After plant shutdown, changed belt in magnetic belt separator. This work required balance of the day. Also checked installation of curtains in shredder.
23	Monday	8.7	6:15 a.m.	Plant start-up.
			6:20-6:35 a.m.	Belt conveyor (C-3) shredder 1 to 2 plugged.
			6:37-6:50 a.m.	Belt conveyor (C-3) plugged.
			6:50-7:10 a.m.	Cut out remaining curtain in shredder 2 in-feed throat.
			8:15-8:40 a.m.	Changed trailers.
			12:55-1:30 p.m.	Vibrating conveyor (C-2) receiving discharge from Shredder 1 plugged.
			2:15-2:35 p.m.	Changed trailers.
			2.5 min	Raw refuse in-feed conveyor (C-1) jammed once.
			15 min	Pneumatic conveyor high-pressure limit switch activated six times.
			3:55 p.m.	Plant shutdown.
				Have started new maintenance shift of one man 3:00 p.m. to 11:00 p.m.
24	Tuesday	11.3	6:10 a.m.	Plant start-up.
			6:20-6:25 a.m.	Vibrating conveyor (C-2) receiving shredder 1 discharge plugged.
			9:35-10:15 a.m.	Changed trailers.
			10:45-11:15 a.m.	ADS heavies belt conveyor (C-7) plugged. ADS reverse air trap plugged.
			1:15-1:25 p.m.	Hopper feeding belt conveyor (C-3) shredder 1 to 2 plugged.
			3:05-3:07 p.m.	Emergency stop on belt conveyor (C-3) tripped by pile up of refuse.
			3:15-3:40 p.m.	Changed trailers.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated once. Time not recorded.
			4:55-5:30 p.m.	ADS plugged. Motor overload relay activated.
			5:30 p.m.	Plant shutdown.

(continued)

TABLE C-1c. (continued)

Day (August 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
25	Wednesday	3.6	2:25 p.m.	Plant start-up.
			2:50-2:55 p.m.	Broken shear pin on raw refuse in-feed conveyor (C-1).
			12 min	Conveyor (C-1) jammed five times.
			6:00 p.m.	Plant shutdown.
26	Thursday	7.1	9:25 a.m.	Plant start-up.
			9:25-9:45 a.m.	Belt conveyor (C-6) to ADS jammed at tail pulley.
			9:55-10:35 a.m.	Flight broke loose in raw refuse in-feed conveyor (C-1).
			2:20-2:25 p.m.	Belt conveyor (C-6) jammed at tail pulley.
			2 min	Conveyor (C-1) jammed once.
			4:30 p.m.	Plant shutdown.
27	Friday	6.5	6:30 a.m.	Plant start-up.
			8:55-9:00 a.m.	Belt conveyor (C-6) to ADS plugged, in turn causing vibrating conveyor (C-5) to plug.
			10:25-10:30 a.m.	Broken shear pin on raw refuse in-feed conveyor (C-1).
			10:35-11:15 a.m.	Broken bolt on conveyor (C-1).
			11:15-11:50 a.m.	Not enough refuse accumulated to process. Shutdown for lunch.
			12:10-12:40 p.m.	Broken bolt on conveyor (C-1).
			1:00 p.m.	Plant shutdown at request of power plant.
30	Monday	9.2	6:10 a.m.	Plant start-up.
			6:40-6:45 a.m.	Hopper feeding belt conveyor (C-3) shredder 1 to 2 plugged.
			7:40-7:45 a.m.	Magnetic belt separator stopped.
			7:55-8:00 a.m.	Fe-metal belt conveyor (C-12) jammed by wire.
			8:15-8:40 a.m.	Changed trailers.
			9:10-9:30 a.m.	ADS feeder plugged.
			9:50-9:55 a.m.	Belt conveyor (C-3) plugged.
			10:35-10:40 a.m.	Fe-metal belt conveyor (C-13) jammed.
			10:45-11:50 a.m.	Cleaned reverse air trap on ADS.
			12:05-12:10 p.m.	Magnetic belt separator stopped.
			1:45-1:50 p.m.	Raw refuse in-feed conveyor (C-1) stopped.
			3:05 p.m.	ADS feeder stopped.
			3:20 p.m.	Plant shutdown.
31	Tuesday	11.1	6:15 a.m.	Plant start-up.
			6:55-7:05 a.m.	ADS motor overload relay activated.
			11:50-12:05 p.m.	Fe-metal conveyor (C-10) jammed.
			12:40-1:00 p.m.	Changed trailers.
			4:55-5:20 p.m.	Hopper to belt conveyor (C-3) shredders 1 to 2 plugged.
			5:20 p.m.	Plant shutdown.

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[a] Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1d. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF SEPTEMBER 1976

Day (September 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
1	Wednesday	0		No processing.
			7:00 a.m.-7:30 p.m.	Changed all the hammers in the primary shredder. This required use of the front-end loader which was out of service for 45 min due to a broken hydraulic line to the bucket. At this point in time estimate hammer life for the total of all working faces as follows: Primary shredder - 20,000 Mg. Secondary shredder - 12,000 Mg.
2	Thursday	10.3	6:15 a.m.	Plant start-up.
			6:20-7:15 a.m.	Belt conveyor (C-6) to ADS tail pulley jammed and vibrating conveyor (C-5) under Shredder 1 plugged as a result.
			9:25-10:05 a.m.	Changed trailers.
			1:05-1:45 p.m.	Shutdown to repair pneumatic conveying line elbow.
			2:00-2:05	Magnetic belt separator stopped.
			4:15-4:25	Vibrating conveyor (C-2) under shredder 1 plugged.
			4:30 p.m.	Plant shutdown.
3	Friday	12.4	6:10 a.m.	Plant start-up.
			7:25-7:30	Fe-metal belt conveyor (C-10) plugged by bed springs and wire.
			9:35-9:40	Raw refuse in-feed conveyor (C-1) stopped.
			12:05-12:35 p.m.	Changed trailers and cleaned out reverse air trap of the ADS blower.
			4:45-5:00	Rotary feeder on ADS plugged.
			6:35 p.m.	Plant shutdown.
6	Monday	0		Holiday - Labor Day.
7	Tuesday	0		Plant not operated to allow power plant to empty surge bin.
8	Wednesday		4:40 p.m.	Plant start-up.
				Magnetic belt separator stopped four times because of high steel content of refuse for a total of 26 min downtime. Raw refuse feed conveyor (C-1) stopped once for added down-
			3 min	time of 3 min.
			7:35 p.m.	Plant shutdown.
9	Thursday	12.8	5:00 a.m.	Plant start-up.
			7:35-7:50	Change trailers.
			9:05-9:35	Tail pulley on raw refuse feed conveyor (C-1) broken.
			9:50-12:00	Primary shredder (1) plugged by rolls of smooth wire.
			N.R.	Magnetic belt separator stopped three times, raw refuse feed conveyor (C-1) once, and the pneumatic high-pressure limit switch three times. Times not recorded.
			5:45 p.m.	Plant shutdown.

(continued)

TABLE C-1d. (continued)

Day (September 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
10	Friday	13.7	5:15 a.m.	Plant start-up.
			9:45-10:40	Front-end loader inoperable.
			11:05-11:15	Feed hopper for belt conveyor (C-3) shredder 1 to 2 bridged.
			12:15-12:30	Trailer changed.
			3:45-4:05	ADS vibrating feeder plugged.
			4:05-4:10	Front end loader stopped.
			5:15-5:50	Front-end loader stopped.
			N.R.	Pneumatic conveyor system high-pressure limit switch activated three times. Time not recorded.
			6:55 p.m.	Plant shutdown.
13	Monday	9.2	7:20 a.m.	Plant start-up.
			2:10-3:10	Change trailers and clean motor of secondary shredder (2)
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			4:30 p.m.	Plant shutdown.
14	Tuesday	3.5	12:30 p.m.	Plant start-up.
			12:55-1:05	ADS rotary feeder breaker switch went off.
			N.R.	Pneumatic conveyor high-pressure limit switch activated twice. Time not recorded.
			2:30-2:40	Air compressor stopped.
			4:00 p.m.	Plant shutdown.
15	Wednesday	10.9	5:05 a.m.	Plant start-up.
			7:15-7:45	Changed trailers in error, load 1 ton light.
			8:15-8:40	Changed trailers.
			9:15-9:25	Vibrating conveyor (C-2) under primary shredder plugged.
			12:25-2:30	ADS heavies bucket elevator (E-1) chain broke.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			4:00 p.m.	Plant shutdown.
16	Thursday	9.3	6:10 a.m.	Plant start-up.
			6:20-6:25	In-feed conveyor (C-1) jammed.
			10:00-10:15	Change trailers.
			11:40-12:00	Rotary feeder on ADS stopped because of thermal overload.
			N.R.	Magnetic separator stopped five times. Time not recorded.
			3:30 p.m.	Plant shutdown.

(continued)

TABLE C-1d. (continued)

Day (September 1976)	Day of Week	Processing Day-Hours^{a/}	Clock time	Description
17	Friday	7.8	6:20 a.m.	Plant start-up.
			7:00-7:20	Change trailers.
			8:00-8:35	In-feed conveyor (C-1) lost some bolts.
			11:40-11:45	Vibrating conveyor (C-2) under primary shredder plugged.
			N.R.	In-feed conveyor (C-1) stopped five times. Time not recorded.
			N.R	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated eight times. Time not recorded.
			2:30 p.m.	Plant shutdown.
20	Monday	7.5	8:00 a.m.	Plant start-up.
			8:15-8:20	Heavies conveyor under ADS (C-7) plugged.
			9:50-9:55	Shear pin in in-feed conveyor (C-1) drive sheared.
			1:25-2:15	Changed trailers. Excessive time due to split heater hose on semitractor repair.
			N.R.	Pneumatic conveyor high-pressure limit switch activated seven times. Time not recorded.
			N.R.	In-feed feed conveyor (C-1) stopped once. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			3:10 p.m.	Plant shutdown.
21	Tuesday	8.0	N.R.	Plant start-up. Time not recorded.
			12 min	Pneumatic conveyor high-pressure limit switch activated three times (12 min). Time not recorded.
			9:05-9:20	Belt conveyor (C-6) to ADS jammed.
			20 min	In-feed conveyor (C-1) stopped four times.
			N.R.	Plant shutdown. Time not recorded.
22	Wednesday	6.2	7:05 a.m.	Plant start-up.
			8:30-8:40	Feed hopper for belt conveyor (C-3) bridged.
			9:25-9:40	Change trailer.
			10:05-10:15	ADS heavies belt conveyor (C-7) plugged.
			11:10-11:40	ADS return air duct plugged.
			12:10-12:15	ADS heavies belt conveyor (C-7) plugged.
			12:50-1:00	ADS heavies belt conveyor (C-7) plugged.
			N.R.	In-feed conveyor (C-1) stopped once. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated three times. Time not recorded.
			1:15 p.m.	Plant shutdown.

(continued)

TABLE G-1d. (continued)

Day (September 1976)	Day of Week	Processing Day-Hours$^{a/}$	Clock Time	Description
23	Thursday	7.8	7:00 a.m.	Plant start-up.
			N.R.	Pneumatic conveyor high-pressure limit switch activated twice. Time not recorded.
			2 min	Stop to check operation of vibrating conveyor (C-2) under primary shredder.
			8:05-8:55	Primary shredder (1) plugged.
			9:05-9:10	ADS heavies bucket elevator (E-1) bridged at discharge point onto belt conveyor (C-14).
			10:10-10:30	Change trailers.
			11:45-12:00	ADS rotary feeder plugged.
			1:55-2:00	ADS heavies belt conveyor (C-7) jammed.
			2:45 p.m.	Plant shutdown.
24	Friday	5.9	9:45 a.m.	Plant start-up.
			N.R.	In-feed conveyor (C-1) stopped twice. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated once. Time not recorded.
			N.R.	Magnetic belt separators stopped twice. Time not recorded.
			9:50-10:00	Feed hopper for belt conveyor (C-3) bridged.
			11:10-11:15	Conveyor belt (C-7) plugged.
			12:00-12:25	Change trailers.
			12:45-12:50	Conveyor belt (C-7) plugged.
			1:20-1:50	ADS air return screen blocked.
			3:20-3:30	In-feed conveyor (C-1) jammed.
			3:40 p.m.	Plant shutdown.
27	Monday	7.8	6:10 a.m.	Plant start-up.
			15 min	Pneumatic conveyor high-pressure limit switch activated four times. Time not recorded.
			N.R.	Magnetic belt separator stopped three times. Time not recorded.
			8:55-9:15	Change trailers.
			9:25-9:35	By-pass chute on secondary shredder inadvertently opened.
			10:20-10:25	In-feed conveyor (C-1) jammed, activating breaker switch.
			12:25-12:29	Pneumatic conveyor high-pressure limit switch activated.
			2:00 p.m.	Plant shutdown.
28	Tuesday	4.4	7:05 a.m.	Plant start-up.
			7:10-7:15	ADS rotary feeder breaker switch activated.
			8:40-8:45	Vibrating conveyor (C-2) under primary shredder plugged.
			9:00-9:05	In-feed conveyor (C-1) plugged.
			10:55-11:00	In-feed conveyor (C-1) jammed.
			N.R.	In-feed conveyor (C-1) stopped. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated twice. Time not recorded.
			11:30 a.m.	Plant shutdown.

TABLE C-1d. (continued)

Day (September 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
29	Wednesday	1.8	7:10 a.m.	Plant start-up.
			8:00-8:20	Change trailers.
			9:15-9:20	Conveyor belt C-7 plugged.
			9:30-9:35	Conveyor belt C-7 plugged.
			9:40 a.m.	Plant shutdown. Link belt motor burned out.
30	Thursday	9.4	6:00 a.m.	Plant start-up.
			6:00-7:45 a.m.	ADS drag conveyor bridged and raw refuse in-feed conveyor (C-1) stop control accidentally hit by front-end loader. By-passed local stop control to operate conveyor.
			8:45-9:20 a.m.	ADS surge bin bridged and belt conveyor (C-6) feeding surge bin jammed at head pulley.
			12:30-12:50	Changed trailers.
			2:15-2:20	Vibrating conveyor (C-2) under shredder 1 plugged due to light paper.
			2:25-2:35 p.m.	ADS surge bin plugged.
			N.R.	Pneumatic conveyor high-pressure limit switch activated five times. Time not recorded.
			3:25 p.m.	Plant shutdown.

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[a] Processing day hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1e. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF OCTOBER 1976

Day (October 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
1	Friday	9.2	7:00 a.m.	Plant start-up.
			8:25-8:35 a.m.	ADS surge bin bridged.
			9:50 a.m.	Conveyor belt (C-7) receiving ADS heavies plugged.
			9:55-10:20 a.m.	Fe-metal belt conveyor (C-12) jammed due to tin cans.
			11:30-11:50 a.m.	Changed trailers.
			1:40-1:50 p.m.	Conveyor belt (C-7) plugged.
			2:50-3:10 p.m.	Conveyor belt (C-7) plugged.
			3:30-4:10 p.m.	Conveyor belt (C-7) plugged.
			N.R.	In-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Magnetic belt separator jammed once. Time not recorded.
			N.R.	Pneumatic conveyor system high-pressure limit switch activated once. Time not recorded.
			4:10 p.m.	Plant shutdown.
4	Monday	8.3	6:10 a.m.	Plant start-up.
			6:20-6:40 a.m.	Feed hopper for belt conveyor (C-3) shredder 1 to 2 bridged.
			8:00-8:20 a.m.	Changed trailers.
			8:30-8:50 a.m.	Vibrating conveyor (C-2) under shredder 1 plugged.
			11:50-12:05	ADS heavies belt conveyor (C-7) plugged.
			2:30 p.m.	Plant shutdown.
5	Tuesday	8.3	7:10 a.m.	Plant start-up.
			8:15-8:30 a.m.	ADS heavies belt conveyor (C-7) plugged.
			9:40-10:00 a.m.	ADS return air duct plugged.
			1:00-2:00 p.m.	Shutdown at request of power plant.
			3:25 p.m.	Plant shutdown.
				Storage bin manufacturer is changing storage bin control center so that speed can be changed on storage bin sweep conveyor. Estimated time of completion is 3 days. Processing plant will continue to operate and RDF will be placed in the storage bin even though sweep conveyor is inoperative.
6	Wednesday	3.7	11:45 a.m.	Plant start-up.
			1:00-1:05 p.m.	Vibrating conveyor (C-2) under shredder 1 plugged.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Pneumatic conveyor high-pressure limit switch activated once. Time not recorded.
			3:25 p.m.	Plant shutdown.

(continued)

TABLE C-1e. (continued)

Day (October 1976)	Day of Week	Processing Day-Hours[a]	Clock Time	Description
7	Thursday	7.8	6:10 a.m.	Plant start-up.
			10:30-10:40 a.m.	ADS heavies belt conveyor (C-7) plugged.
			10:40-10:45	Broken shear pin in raw refuse in-feed conveyor (C-1).
			11:20-12:50 p.m.	Changed trailers.
			1:10-1:30 p.m.	Belt conveyor (C-7) plugged.
			2:10-2:15 p.m.	In-feed conveyor (C-1) jammed.
			N.R.	Pneumatic conveyor high pressure limit switch activated twice. Time not recorded.
			N.R.	In-feed conveyor (C-1) stopped five times. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			3:00 p.m.	Plant shutdown.
8	Friday	11.7	7:05 a.m.	Plant start-up.
			7:22-10:35 a.m.	Motor burned out on ADS vibrating feeder.
			4:00-4:25 p.m.	Changed trailers.
			N.R.	Raw refuse in feed conveyor (C-1) stopped three times. Time not recorded.
			6:45 p.m.	Plant shutdown.
11	Monday	7.2	8:15 a.m.	Plant start-up.
			11:45-12:15 p.m.	Changed trailers.
			3:15-3:20 p.m.	Removed tree stump from raw refuse in-feed conveyor (C-1).
			30 min	Pneumatic conveyor high-pressure limit switch activated 12 times.
			5 min	Raw refuse in-feed conveyor (C-1) stopped twice.
			3:25 p.m.	Plant shutdown.

[a] Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1e. (continued)

Day (October 1976)	Day of week	Processing day-hours a/	Clock time	Description
12	Tuesday	8.3	7:10 a.m.	Plant start-up.
			8:05-8:30	Clean ADS air trap.
			9:50-10:35	Changed trailers.
			11:05-11:10	Feed hopper for belt conveyor (C-3)shredder 1 to 2 bridged.
			3:25 p.m.	Plant shut down.
				Note: Combustion power maintenance person has worked for 3 days adjusting speed switches on conveyors. Also installed automatic shut-off switch on magnetic belt separator to prevent belt damage.
13	Wednesday	7.3	7:05 a.m.	Plant start-up.
			7:45-8:15	Changed trailers.
			9:50-10:00	Vibrating conveyor (C-2) under shredder 1 plugged.
			12:45-1:30	ADS airlock screen blocked.
			1:40-1:45	Removed heavy steel from ferrous metal belt conveyor (C-12).
			N.R.	Pneumatic conveyor system high pressure limit switch activated once. Time not recorded.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed once. Time not recorded.
			2:25 p.m.	Plant shut down.
14	Thursday	4.9		Note: Start-up delayed at request of power plant. Cause attributed to silica slag buildup directly above fire ports in spreader-stoker boiler No. 5, reducing air intake and improper air:fuel mixture.
			10:30 a.m.	Plant start-up.
			2:30-2:40	Ferrous metal belt conveyor (C-11) came off tracks.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			3:25 p.m.	Plant shut down.
15	Friday	5.3	7:05	Plant start-up.
			7:45-8:10	Changed trailers.
			11:20-12:00 p.m.	ADS heavies belt conveyor (C-7) plugged.

(continued)

TABLE C-1e. (continued)

Day (October 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
			12:00-12:20	Cleaned out ADS reverse air trap.
			12:20	Cyclone bridged when system restart attempted.
			N.R.	Raw refuse in-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Magnetic belt separator stopped three times. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated once. Time not recorded.
			12:20 p.m.	Plant shut down.
18	Monday	8.3	6:10 a.m.	Plant start-up.
			7:05-7:20	Changed trailers.
			11:00-11:25	Changed trailers.
			11:50-12:05	Cleaned out ADS reverse air trap.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated 14 times. Times not recorded.
			2:30 p.m.	Plant shut down.
19	Tuesday	8.4	7:05 a.m.	Plant start-up.
			9:00-9:10	ADS feeder motor overload relay activated.
			9:10-9:40	Changed trailers.
			10:50-11:10	Cleaned out ADS reverse air trap.
			11:35-1:45	Screw conveyor feeding pneumatic conveying system plugged.
			N.R.	In-feed conveyor (C-1) plugged twice. Time not recorded.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated four times. Time not recorded.
			3:30 p.m.	Plant shut down.
20	Wednesday	7.6	7:00 a.m.	Plant start-up.
			8:25-8:30	Feed hopper for belt conveyor (C-3) shredder 1 to 2 bridged.
			9:10-9:25	Changed trailers.
			N.R.	In-feed conveyor (C-1) stopped once. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated eight times. Time not recorded.

(continued)

TABLE C-1e. (continued)

Day (October 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
20 (Concluded)			2:35 p.m.	Plant shut down. Combustion power not running.
21	Thursday	5.5	7:05 a.m.	Plant start-up.
			9:00-9:15	Ferrous metal belt conveyor (C-12) jammed.
			12:35 p.m.	Plant shut down. Low on refuse.
22	Friday	7.7	7:30 a.m.	Plant start-up.
			8:30-8:35	Hopper feeding belt conveyor (C-3) shredders 1 to 2 bridged.
			1:15-1:35	Changed trailers.
			2:05-2:25	Vertical section of ADS drag conveyor plugged.
			3:00	Primary shredder jammed with telephone wire.
			3:10 p.m.	Plant shut down.
25	Monday	8.3	7:05 a.m.	Plant start-up.
			10:50-11:15	Changed trailers.
			N.R.	In-feed conveyor (C-1) jammed five times. Time not recorded.
			N.R.	Magnetic belt separator stopped four times. Time not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated 10 times. Time not recorded.
			3:25	Changed trailers.
			3:25 p.m.	Plant shut down.
26	Tuesday	5.0	10:00 a.m.	Plant start-up.
			11:10-11:20	Vertical section of ADS drag conveyor plugged.
			N.R.	Magnetic belt separator stopped three times. Time not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated three times.
			3:00 p.m.	Plant shut down.
27	Wednesday	5.3	10:10 a.m.	Plant start-up.
			11:45-12:25	ADS heavies belt conveyor (C-7) plugged. Cleaned ADS return air screen.
			1:00-1:35	Vibrating conveyor (C-2) under primary shredder plugged.

(continued)

TABLE C-1e. (continued)

Day (October 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
27 (Concluded)			2:55-3:20	Rotary feeder on ADS plugged.
			3:20	Screw conveyor feeding pneumatic conveying system plugged.
			3:25	Plant shut down.
28	Thursday	10.9	7:10 a.m.	Plant start-up.
			7:35-9:45	Screw conveyor feeding pneumatic conveying system plugged.
			9:45-9:50	ADS heavies belt conveyor (C-7) plugged.
			11:05-11:10	Ferrous metal belt conveyor (C-12) jammed.
			11:25-12:45	Screw conveyor feeding pneumatic conveying system plugged.
			12:45-1:05	Changed trailers.
			2:30-2:35	Vibrating conveyor (C-2) under primary shredder plugged.
			N.R.	Combustion power did not run.
			6:05 p.m.	Plant shut down.
29	Friday	1.3	7:00 a.m.	Plant start-up.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			8:20 a.m.	Plant shut down.

[a/] Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1f. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF NOVEMBER 1976

Day (November 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
1	Monday	8.3	8:25 a.m.	Plant start-up.
			10:35-11:20	ADS return air duct plugged.
			1:35-2:20	Changed trailer.
			4:20-4:40	Belt conveyor (C-3) stopped to replace broken drive belt.
			N.R.	In-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Magnetic belt separator stopped six times. Time not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated 20 times. Time not recorded.
			4:45 p.m.	Plant shut down.
2	Tuesday	10.0	6:00 a.m.	Plant start-up.
			6:15-6:20	Hopper feeding belt conveyor (C-3) between shredders 1 and 2 bridged.
			9:05-9:25	Changed trailers.
			2:25-2:45	Changed trailers.
			N.R.	In-feed conveyor (C-1) stopped four times. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated six times. Time not recorded.
			4:00 p.m.	Plant shut down.
3	Wednesday	6.3	7:00 a.m.	Plant start-up.
			10:50-11:00	ADS heavies belt conveyor (C-7) plugged.
			11:20-11:50	Changed trailers.
			12:25-1:00	Vibrating conveyor (C-2) under shredder 1 jammed.
			N.R.	In-feed conveyor (C-1) stopped eight times. Time not recorded.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated once. Time not recorded.
			1:20	Shredder 1 jammed with a log.
			1:20 p.m.	Plant shut down.

(continued)

TABLE C-1f. (continued)

Day (November 1976)	Day of week	Processing day-hours[a]	Clock time	Description
4	Thursday	7.3	7:05 a.m.	Plant start-up.
			9:55-10:15	Replace drive belts on (C-3) conveyor.
			11:05-11:25	Changed trailers.
			11:50-12:15	Cleaned ADS return air trap.
			N.R.	In-feed conveyor (C-1) plugged seven times. Time not recorded.
			N.R.	Magnetic belt separator stopped five times. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated four times. Time not recorded.
			2:20 p.m.	Plant shut down.
5	Friday	8.6	7:05	Plant start-up.
			8:00-8:15	Vibrating conveyor (C-2) under shredder 1 plugged.
			9:45-10:00	Belt conveyor (C-3) threw belt, replaced.
			10:40-10:55	Changed trailers.
			N.R.	In-feed conveyor (C-1) jammed seven times. Time not recorded.
			N.R.	Magnetic belt separator stopped three times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated five times. Time not recorded.
6	Saturday			Fire discovered at about 4:00 a.m. in the plant processing area. Firemen broke through skylight and extinguished fire by 6:00 a.m. Considerable smoke damage in office areas; one TV camera destroyed. Electrical wiring melted in many places. Conveyor C-6 melted and hydraulic system of shredder 2 melted. Control room windows broken, C-6 hopper inner liner burned, C-6 drive motor burned/melted, in-feed hopper from C-5 to C-6 warped beyond repair. Wall-hung vacuum line destroyed, all insulation on water pipes above C-6 conveyor burned off, two telephones melted, and all outside air controls burned out. Several light fixtures burned, and styrofoam insulation burned.

(continued)

TABLE C-1f. (continued)

Day (November 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
8-19	2 weeks	4.0		Plant not operational because of fire damage and repair efforts. Plant personnel engaged in cleaning up operating areas. Total operating time of approximately 4 hours involved in testing equipment and repairs prior to resuming full-scale operations.
22	Monday	4.0	6:00 p.m.	Plant start-up for test run.
			8:10-8:20	Feed hopper for belt conveyor (C-3) shredder 1 to 2 bridged.
			9:50-9:55	In-feed conveyor (C-1) shear pin broken.
			N.R.	In-feed conveyor (C-1) jammed four times. Time not recorded.
			N.R.	Magnetic belt separator stopped seven times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated once. Time not recorded.
			10:05 p.m.	Plant shut down.
23	Tuesday	1.8	12 Noon	Plant start-up.
			12:50-1:05	Cleaned ADS air return trap.
			1:50	ADS drag conveyor lost several flights.
			N.R.	In-feed conveyor (C-1) jammed twice. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			1:50 p.m.	Plant shut down.
24	Wednesday	8.3	7:00 a.m.	Plant start-up.
			10:00-10:20	Changed trailer.
			1:40-1:55	ADS feeder plugged.
			N.R.	In-feed conveyor (C-1) jammed eight times. Time not recorded.
			N.R.	Magnetic belt separator stopped six times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated four times. Time not recorded.
			3:20 p.m.	Plant shut down.

(continued)

TABLE C-1f. (continued)

Day (November)	Day of week	Processing day-hours[a]	Clock time	Description
25	Thursday	-0-		Thanksgiving holiday.
26	Friday	7.3	8:05 a.m.	Plant start-up.
			9:20-9:35	Belt conveyor (C-6) to ADS jammed.
			9:50-9:55	In-feed conveyor (C-1) jammed, activating breaker switch.
			10:45-11:15	Clean ADS return air trap. Ferrous metal belt conveyor (C-13) jammed.
			2:05-2:15	Changed trailer.
			N.R.	In-feed conveyor (C-1) jammed 11 times. Times not recorded.
			N.R.	Magnetic belt separator stopped 16 times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated four times. Times not recorded.
			3:20 p.m.	Plant shut down.
29	Monday	8.2	8:10 a.m.	Plant start-up.
			9:30	Stopped operations, no reason provided.
			11:05	Operations restarted.
			11:55-12:05	Belt conveyor (C-6) to ADS jammed.
			1:40-1:50	Belt conveyor (C-6) to ADS bridged.
			N.R.	In-feed belt conveyor (C-1) plugged once. Time not recorded.
			N.R.	Magnetic belt separator stopped 17 times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated five times. Times not recorded.
			4:20 p.m.	Plant shut down.
30	Tuesday	9.3	7:10 a.m.	Plant start-up.
			8:05-8:10	Latch on hopper feeding belt conveyor (C-3) broke.
			8:15-8:45	Vibrating conveyor (C-2) plugged.
			10:20-10:30	In-feed conveyor (C-1) jammed activating breaker switch.
			10:40-11:05	In-feed conveyor (C-1) broken bolt repair.
			11:40-1:05	ADS heavies belt conveyor (C-7) jammed.
			1:10-1:25	Vertical section of ADS drag conveyor plugged.
			2:50-3:05	Changed trailers.
			N.R.	In-feed conveyor (C-1) plugged eight times. Times not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated three times. Times not recorded.
			4:25 p.m.	Plant shut down.

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[a] Processing day-hours is time span from first plant start-up to last plant shutdown, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start-up and after plant shutdown. Also actual hours spent shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-1g. DAILY RECORD OF REFUSE PROCESSING PLANT ACTIVITY FOR THE MONTH OF DECEMBER 1976

Day (December 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
1	Wednesday	9.3	7:05 a.m.	Plant start-up.
			7:30-7:40	Vibrating conveyor (C-2) plugged.
			8:30-8:45	Adjusted magnetic belt separator raised one link.
			10:30-10:35	In-feed conveyor (C-1) activated breaker switch.
			12:25-12:30	In-feed conveyor (C-1) broken shear pin.
			1:00-1:55	Hydraulic hose on front end loader split.
			2:30-2:50	Changed trailers.
			2:50-3:00	Repaired leaking hydraulic hose on front-end loader.
			N.R.	In-feed conveyor (C-1) plugged 21 times. Times not recorded.
			N.R.	Magnetic belt separator stopped 16 times. Times not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated six times. Times not recorded.
			4:25 p.m.	Plant shut down.
2	Thursday	8.6	6:00 a.m.	Plant start-up.
			6:45-6:50	Door on hopper feeding (C-3) belt conveyor opened.
			8:10-8:20	Vibrating conveyor (C-2) plugged.
			9:25-9:40	Changed trailers.
			N.R.	In-feed conveyor (C-1) stopped 11 times. Time not recorded.
			N.R.	Magnetic belt separator stopped nine times. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated 10 times. Time not recorded.
			2:35 p.m.	Plant shut down.
3	Friday	8.2	7:05 a.m.	Plant start-up.
			7:10-7:20	Vibrating conveyor (C-2) motor would not start due to extremely cold temperatures.
			8:00-8:15	Stopped to clear primary shredder.
			8:40-8:45	Stopped to clear jammed primary shredder.
			12:05-12:50	Changed trailers.
			1:05-1:10	ADS heavies belt conveyor (C-7) jammed.
			N.R.	In-feed conveyor (C-1) plugged nine times. Time not recorded.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			3:15 p.m.	Plant shut down.

(continued)

TABLE C-1g. (continued)

Day (December)	Day of week	Processing day-hours[a/]	Clock time	Description
6	Monday	7.5	6:00 a.m.	Plant start-up.
			8:25-8:30	Vibrating conveyor (C-5) jammed activating breaker switch.
			8:55-9:25	Changed trailers.
			9:30-9:40	Vibrating conveyor (C-5) jammed activating breaker switch.
			11:10-11:20	Pneumatic conveyor high pressure limit switch activated.
			12:05-12:15	ADS drag conveyor plugged in vertical section.
			12:50-1:30	PSI blower switch activated.
			N.R.	In-feed conveyor (C-1) jammed 10 times. Times not recorded.
			N.R.	Pneumatic conveyor high pressure limit switch activated seven times. Times not recorded.
			1:30 p.m.	Plant shut down.
				Note: Aluminum metal separator inoperable since November fire. Water pipes are frozen, need a few electrical repairs. Hot water recirculating system in pipes being considered.
7	Tuesday	11.6	7:05 a.m.	Plant start-up.
			7:20-7:30	Vibrating conveyor (C-2) activated breaker switch.
			7:30-7:55	Front-end loader stopped running.
			11:10-11:30	Changed trailer.
			12:25-12:30	Vibrating conveyor (C-5) activated breaker switch.
			12:50-3:05	PSI blower inoperable, pipeline plugged at bin wear-back.
			N.R.	In-feed conveyor (C-1) plugged nine times. Time not recorded.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			N.R.	Pneumatic conveyor system high pressure limit switch activated nine times. Times not recorded.
			6:40 p.m.	Plant shut down.
				Note: Temperature outside -12°F today.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of Week	Processing day-hours[a]	Clock time	Description
8	Wednesday	8.5	7:00-11:00 a.m.	Hammers in shredders 1 and 2 replaced.
			12 Noon	Plant start-up.
			1:30-1:50	Changed trailers.
			3:15-3:20	Vibrating conveyor (C-5) activated breader switch.
			N.R.	In-feed conveyor (C-1) plugged once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated once. Time not recorded.
			3:30 p.m.	Plant shut down.
9	Thursday	8.4		Outside temperature up to +38°F today. All fire and water lines thawed. Pipes began falling down and water poured onto floor. Plant design specifications did not include insulated pipes so most have been frozen in past few days.
			7:05 a.m.	Plant start-up.
			7:10-7:30	Belt conveyor (C-3) would not start and ADS heavies belt conveyor (C-7) plugged.
			11:45-11:50	Vibrating conveyor (C-5) stopped.
			12:15-12:35	Changed trailers.
			12:45-12:50	ADS feeder jammed.
			N.R.	In-feed conveyor (C-1) jammed five times. Times not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated twice. Time not recorded.
			3:30 p.m.	Plant shut down.
10	Friday	9.4	7:05 a.m.	Plant start-up.
			8:30-11:55	Shut down plant to thaw frozen water pipe.
			2:00-2:25	Change trailer.
			N.R.	In-feed conveyor (C-1) jammed once. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated twice. Time not recorded.
			4:30 p.m.	Plant shut down.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of week	Processing day-hours[a]	Clock time	Description
13	Monday	8.3	6:30 a.m.	Plant start-up.
			7:25-9:05	Vertical section of pneumatic conveying pipe inside plant from cyclone to ADS screw feeder plugged.
			9:55-10:10	Fe-metal belt conveyor (C-10) plugged.
			12:35-12:55	Changed trailer.
			2:30-3:00	ADS return air plugged.
			N.R.	In-feed conveyor (C-1) jammed four times. Time not recorded.
			N.R.	Magnetic belt separator stopped twice. Time not recorded.
			3:10 p.m.	Plant shut down.
14	Tuesday	8.3	7:00 a.m.	Plant start-up.
			7:20-7:25	Hopper feeding belt conveyor (C-3) plugged with wire.
			9:10-9:15	ADS heavies bucket elevator (E-1) plugged.
			9:20-9:30	ADS return air cleaned.
			10:25-10:45	Changed trailer.
			2:45-2:53	Heavier conveyor (C-7) under ADS jammed.
			3:10-3:20	Front-end loader stopped. Wire entangled around driveshaft.
			N.R.	In-feed conveyor (C-1) plugged five times. Time not recorded.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated seven times. Times not recorded.
			3:20 p.m.	Plant shut down.
15	Wednesday	3.2	10:10 a.m.	Plant start-up.
			11:10-11:30	Changed trailer.
			1:20	Bearing out on oscillating link belt conveyor
			N.R.	In-feed conveyor (C-1) jammed twice. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated three times. Time not recorded.
			1:20 p.m.	Plant shut down.
16	Thursday	8.3	7:10 a.m.	Plant start-up.
			N.R	Front-end loader brakes inoperable, one-half day for repair. Used Hough loader.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
16 (Continued)			9:35-9:50	Cleaned ADS air return.
			11:00-11:15	Changed trailer.
			N.R.	Magnetic belt separator stopped once. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated seven times. Times not recorded.
			3:30 p.m.	Plant shut down.
17	Friday	9.3	7:10 a.m.	Plant start-up.
			7:40-8:35	Heavies conveyor (C-7) under ADS jammed; cyclone plugged.
			9:00-10:35	Cyclone plugged, adjusted rotary feeder blades.
			10:45-11:00	Changed trailers.
			12:35-12:40	Fe-metal belt conveyor (C-10) jammed with wire.
			1:10-3:00	Vertical section of flight conveyor plugged and motor on vibrating screen broke loose from mounts.
			N.R.	Pneumatic conveying system high pressure limit switch activated three times. Times not recorded.
			N.R.	Baled corrugated boxboard in afternoon.
			4:30 p.m.	Plant shut down.
20	Monday	16.0	6:00 a.m.	Plant start-up.
			7:10-7:40	Changed trailer.
			8:40-9:00	ADS feeder plugged and surge bin bridged.
			10:05-11:00	Oscillating conveyor stopped, adjusted setting.
			11:35-2:10	Repair motor wiring.
			2:40-3:10	Repair controls on air compressor for instrument air.
			4:25-4:30	In-feed conveyor (C-1) jammed activating breaker switch.
			4:40-4:50	ADS surge bin bridged.
			5:05-5:10	In-feed conveyor (C-1) jammed activating breaker switch.
			5:20-6:05	Changed trailers.
			6:15-6:40	ADS surge bin bridged.
			10:00 p.m.	Plant shut down.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of week	Processing day-hours[a/]	Clock time	Description
21	Tuesday	9.3	6:00 a.m.	Plant start-up.
			6:40-6:42	Pneumatic conveying system high pressure limit switch activated.
			6:58-6:59	Pneumatic conveying system high pressure limit switch activated.
			7:21-7:25	Pneumatic conveying system high pressure limit switch activated.
			N.R.	In-feed conveyor (C-1) jammed 32 times. Times not recorded.
			7:59-8:10	Vibrating conveyor (C-5) stopped.
			10:45-11:00	Vibrating conveyor (C-2) plugged.
			11:10-11:30	Belt conveyor (C-3) jammed at head pulley.
			11:45-11:55	ADS surge bin bridged.
			12:05-12:10	ADS surge bin bridged.
			1:15-1:25	In-feed conveyor (C-1) jammed.
			1:35-1:45	Belt conveyor (C-3) jammed.
			2:15-2:20	ADS surge bin bridged.
			3:15 p.m.	Plant shut down.
22	Wednesday	5.5	10:00 a.m.	Plant start-up.
			10:50	Belt conveyor (C-3) backed up.
			N.R.	Changed trailer. Time not recorded.
			N.R.	In-feed conveyor (C-1) jammed 12 times. Times not recorded.
			3:30 p.m.	Plant shut down.
23	Thursday	8.3	7:00 a.m.	Plant start-up.
			8:45-10:00	Heavies conveyor (C-1) jammed.
			11:40-12:30	ADS return air and cyclone plugged.
			1:40-2:15	Heavies conveyor (C-7) plugged.
			3:18 p.m.	Plant shut down.
24	Friday	4.0	7:05 a.m.	Plant start-up.
			8:20-9:10	ADS return air cleaned.
			11:05 a.m.	Plant shut down.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of week	Processing day-hours[a]	Clock time	Description
27	Monday	8.1	7:00 a.m.	Plant start-up.
			7:45-10:10	Vibrating screen motor broken from base. Rewelded.
			10:50-11:40	Heavies conveyor (C-7) jammed.
			12:15-12:20	Heavies conveyor (C-7) jammed.
			1:25-1:35	Heavies conveyor (C-7) jammed.
			2:10-2:30	Cleaned ADS return air screen.
			3:05	Fire in primary shredder. Plant shut down and fire extingished by 3:30 p.m. Shredder cleaned out.
			N.R.	In-feed conveyor (C-1) plugged twice. Time not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated once. Time not recorded.
			3:05 p.m.	Plant shut down.
28	Tuesday	8.1	7:15 a.m.	Plant start-up.
			9:30-10:00	Changed trailer.
			N.R.	In-feed conveyor (C-1) jammed twice. Time not recorded.
			N.R.	Magnetic separator stopped once. Time not recorded.
			3:10 p.m.	Plant shut down.
29	Wednesday	6.3	10:15 a.m.	Plant start-up.
			11:05-11:35	Change trailer.
			2:05-2:10	Vibrating conveyor (C-5) activated breaker switch.
			3:15-3:35	Cleaned ADS return air screen.
			N.R.	In-feed conveyor (C-1) stopped seven times. Times not recorded.
			N.R.	Pneumatic conveying system high pressure limit switch activated once. Time not recorded.
			4:30 p.m.	Plant shut down.
30	Thursday	6.0	10:20 a.m.	Plant start-up.
			11:05-11:40	Changed trailer.
			2:40-3:25	Heavies conveyor (C-7) jammed and cyclone bridged.
			N.R.	In-feed conveyor (C-1) jammed six times. Times not recorded.
			4:25 p.m.	Plant shut down.

(continued)

TABLE C-1g. (continued)

Day (December 1976)	Day of week	Processing day-hours[a]	Clock time	Description
31	Friday	6.0	10:40 a.m.	Plant start-up.
			12:30-12:45	Changed trailer.
			N.R.	In-feed conveyor (C-1) stopped six times. Time not recorded.
			4:45 p.m.	Plant shut down. No refuse to process.

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[a] Processing day-hours is time span from first plant start-up to last plant shut down, which is the time period the plant must be fully staffed. Processing day-hours does not include maintenance and cleaning hours prior to plant start up and after plant shutdown. Also actual hours shredding refuse is less than processing day-hours due to various categories of downtime.

TABLE C-2. RAW REFUSE DELIVERED BY PRIVATE INDIVIDUALS
(Private automobiles and pickup trucks)

Day	Day of Week	Total Refuse Delivered (kg)	Number of Private Vehicles	Average Weight (kg/vehicle)
(June 1976)				
9	Wednesday	3,852	72	53.5
10	Thursday	3,978	60	66.3
11	Friday	4,563	68	67.1
12	Saturday	11,799	126	93.6
14	Monday	3,973	74	53.7
15	Tuesday	9,317	84	110.9
16	Wednesday	8,391	63	133.2
17	Thursday	5,062	55	92.0
18	Friday	5,851	82	71.4
23	Wednesday	1,860	69	27.0
24	Thursday	2,440	74	33.0
25	Friday	3,057	66	46.3
29	Tuesday	3,438	53	64.9
(July 1976)				
1	Thursday	3,565	70	50.9
2	Friday	7,530	115	65.5
3	Saturday	4,618	70	66.0
6	Tuesday	10,414	115	90.6
7	Wednesday	3,810	70	54.4
8	Thursday	3,193	41	77.9
9	Friday	4,944	65	76.1
10	Saturday	11,703	139	84.2
12	Monday	6,858	63	108.9
13	Tuesday	5,770	53	108.9
14	Wednesday	3,946	43	91.8
15	Thursday	4,354	54	80.6
16	Friday	6,096	62	98.3
17	Saturday	12,619	119	106.0
19	Monday	15,966	53	301.3
20	Tuesday	12,147	52	233.6
21	Wednesday	6,323	44	143.7
22	Thursday	5,153	46	112.0
23	Friday	5,924	53	111.8
24	Saturday	11,331	180	63.0

(continued)

TABLE C-2. (continued)

Day	Day of Week	Total Refuse Delivered (kg)	Number of Private Vehicles	Average Weight (kg/vehicle)
(July 1976) (Concluded)				
26	Monday	10,687	70	152.7
27	Tuesday	4,799	64	75.0
28	Wednesday	7,003	48	145.9
29	Thursday	17,382	72	241.4
30	Friday	6,840	75	91.2
31	Saturday	8,020	139	57.7
(August 1976)				
11	Wednesday	5,815	47	123.7
12	Thursday	6,677	53	126.0
13	Friday	6,051	75	80.7
14	Saturday	9,344	151	61.9
16	Monday	8,355	80	104.4
17	Tuesday	4,745	52	91.3
21	Saturday	12,628	139	90.8
25	Wednesday	4,835	44	109.9
26	Thursday	7,824	51	153.4
27	Friday	6,822	76	89.8
28	Saturday	13,535	183	74.0
30	Monday	10,287	82	125.5
Total		365,494	3,954	92.4[a]
Standard deviation				50.66
Confidence interval at 95% confidence level				± 14.2
Number of days in survey = 51				

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[a] Total refuse delivered divided by total vehicles.

TABLE C-3. PROCESSING PLANT WORK STATION JOB DESCRIPTION

Title	No. Employees	Work Station and Job Description
Full-Time Employees (Regular Shift 8:00-4:30; Maintenance Shift 2:00-10:30)		
Plant Superintendent (Professional, managerial)	1	Work Station: Office and Control Room Regular Shift Job Description: Plans, assigns, and supervises all plant operations and operations at landfill. Recommends and directs changes in plant operation and methods. Assists in scheduled visits and in safety of visitors and employees. Inspects and supervises maintenance and major overhaul of equipment. Maintains records and prepares reports on plant operation, mass flow income, and expense records, etc. Schedules work shifts. Responds to emergency calls regarding plant equipment breakdowns and power outages. Maintains good public relations. (See City of Ames data for education and skill requirements and for experience needed.
Chief Operator	1	Work Station: Main Station - Control Panel located in control room. Other areas in plant as needed for maintenance or supervision. Regular Shift Duties: 1. Operates plant machinery 2. Supervises all operating and maintenance employees 3. Supervises cleaning, maintenance, and repair of building and equipment 4. Trains new employees 5. Reviews plant records, meters 6. Keeps records and prepares daily and monthly reports on plant operations 7. Assists in planning and designing changes in plant and equipment 8. Schedules work shifts of operating personnel and assists in selecting new operations and maintenance personnel.
End Loader Operator	1	Work Station: Front End Loader located on tipping room floor - Landfill. Regular Shift Duties: 1. Pushes solid waste up onto pile. Pushes solid waste onto Z-pan conveyor (C-1). 2. Visually inspects solid waste for hazardous items 3. Assists in directing traffic through the plant 4. Covers material in landfill - demolition material once per week, 3M material once per day. Requires 2 hr in morning (8-10 a.m.)
Maintenance Man II	3	Man No. 1: Electrical Maintenance Work Station: Process Plant Maintenance Shift: 2:00-10:30 p.m. Duties: General maintenance on electric motors, wiring, and related equipment as required. Man No. 2: Mechanical Maintenance Work Station: Process Plant Maintenance Shift: 2:00-10:30 p.m. Duties: 1. Performs mechanical maintenance on process equipment and conveyors as required 2. Determines ways of minimizing maintenance workload through planned replacement of parts, adjustment of operating speeds, etc. Man No. 3: Welding Work Station: Process Plant Maintenance Shift: 2:00-10:30 p.m. Duties: 1. Welds hammers 2. Assists when other Maintenance Men II's are unable to perform a job because of other work being done in paint.

(continued)

TABLE C-3. (continued)

Title	No. Employees	Work Station and Job Description
Maintenance Man I	2	Man No. 1: General Maintenance Work Station: 1. Tipping Room Floor 2. Paper Baler Room 3. Log Chipper Regular Shift Duties: 1. Assists customers on tipping room floor 2. Operates paper baler 3. Keeps floor clean (operates sweeper) 4. Operates log chipper 5. Assists in looking for hazardous waste material 6. Minor maintenance work (misc.) Man No. 2: General Maintenance Work Station: Tipping Room Floor Maintenance Shift: 2:00-10:30 p.m. Duties: 1. Greasing equipment 2. Assist Maintenance Men II's as needed
Truck Driver	1	Work Station: Truck or Tipping Room Floor Regular Shift Duties: 1. Haul material to landfill 2. Change ferrous trailers (30 ft, 4 wheel) 3. Assist in cleaning heavy metal storage area of tipping floor 4. Occasional maintenance (as a Maintenance Man I)
Total Full-Time Employees in Plant:	Supervisory: 1 Full-time hourly: 8 Total full-time: 9	
Part-Time Employees		
Tour Guide	1	Work Station: Office and Control Room, also Conference Room Regular Shift: (Half time) Duties: 1. Conducts tour of plant 2. Explains operation of plant to visitors, shows film cassette description of plant history and function
Janitor-Office	1	Work Station: 1. Office and Control Room 2. Occasionally tipping floor Regular Shift: (half time, 8-12 a.m.) Duties: 1. Clean up office and control room 2. Assist if needed on tipping floor to direct customers, etc.
Janitor-Plant	3	Work Station: Process Plant Shift: (Half time, 4-8 p.m.) Duties: Clean up processing area of plant.
Total Part-Time Employees in Plant:	5	

TABLE C-4a. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF JUNE 1976

Day June 1976	Day of Week	Raw Refuse In-Feed (hr)[a/]	Plant Operating (hr)[b/]	Use Factor (in-feed hours as percent of plant operating hours)
1	Tuesday	6.4	9.3	68.8
2	Wednesday	6.9	7.9	87.3
3	Thursday	8.1	11.0	73.6
4	Friday	8.6	9.6	89.6
7	Monday	3.6	4.5	80.0
8	Tuesday	4.7	6.7	70.1
9	Wednesday	5.7	6.3	90.5
10	Thursday	4.9	7.1	69.0
11	Friday	6.2	7.5	82.7
14	Monday	0	0	General maintenance
15	Tuesday	5.7	7.6	75.0
16	Wednesday	0	0	ADS drag conveyor down
17	Thursday	3.2	6.7	47.8
18	Friday	0	0	ADS drag conveyor repair
19	Saturday	3.0	3.9	76.9
21	Monday	1.4	2.1	66.7
22	Tuesday	2.0	2.8	71.4
23	Wednesday	2.4	3.7	64.9
24	Thursday	3.6	4.4	81.8
25	Friday	3.3	4.0	82.5
28	Monday	4.7	8.7	54.0
29	Tuesday	5.5	6.4	85.9
30	Wednesday	3.0	5.0	60.0
Total		98.1	125.2	73.4
Average		4.91	6.26	

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a/ Recorded hours from running time meter on in-feed conveyor (C-1).

b/ Recorded hours from running time meter on pneumatic conveying feeder.

TABLE C-4b. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF JULY 1976

Day July 1976	Day of Week	Raw Refuse In-feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
1	Thursday	6.6	8.2	80.5
2	Friday	6.2	8.5	72.9
5	Monday	0	0	Holiday
6	Tuesday	6.3	8.3	75.9
7	Wednesday	3.9	4.7	83.0
8	Thursday	3.9	4.9	79.6
9	Friday	3.5	5.4	64.8
12	Monday	3.2	5.1	62.7
13	Tuesday	5.5	8.1	67.9
14	Wednesday	4.5	6.0	75.0
15	Thursday	5.1	7.0	72.9
16	Friday	4.1	6.1	67.2
19	Monday	3.4	4.8	70.8
20	Tuesday	5.1	7.0	72.9
21	Wednesday	5.8	7.0	82.9
22	Thursday	4.4	5.6	78.6
23	Friday	2.4	4.3	55.8
26	Monday	5.8	7.0	82.9
27	Tuesday	6.5	8.5	76.5
28	Wednesday	3.0	3.4	88.2
29	Thursday	3.7	5.7	64.9
30	Friday	6.2	8.0	77.5
Total		99.1	133.6	74.2
Average		4.72	6.36	

[a] Recorded hours from running time meter on in-feed conveyor (C-1).
[b] Recorded hours from running time meter on pneumatic conveyor feeder.

TABLE C-4c. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF AUGUST 1976

Day August 1976	Day of Week	Raw Refuse In-Feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
2	Monday	0.2	0.7	28.6
3	Tuesday	1.9	2.7	70.4
4	Wednesday	9.9	11.7	84.6
5	Thursday	6.4	10.9	58.7
6	Friday	8.4	10.5	80.0
9	Monday	6.0	7.1	84.5
10	Tuesday	6.0	6.7	89.6
11	Wednesday	2.5	4.2	59.5
12	Thursday	9.3	10.4	89.4
13	Friday	5.7	7.4	77.0
16	Monday	5.6	7.8	71.8
17	Tuesday	5.2	7.0	74.3
18	Wednesday	0	0	ADS drag conveyor maintenance
19	Thursday	7.1	10.6	67.0
20	Friday	2.3	3.5	65.7
23	Monday	7.2	9.5	75.8
24	Tuesday	8.4	11.3	74.3
25	Wednesday	3.4	3.7	91.9
26	Thursday	5.8	6.5	89.2
27	Friday	4.3	5.5	78.2
30	Monday	6.2	8.5	72.9
31	Tuesday	9.7	11.2	86.6
Total		121.5	157.4	77.2
Average		5.79	7.50	

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[a] Recorded hours from running time meter on in-feed conveyor (C-1).

[b] Recorded hours from running time meter on pneumatic conveying feeder.

TABLE C-4d. DAILY PROCESSING HOURS—REFUSE PROCESSING PLANT FOR THE MONTH OF SEPTEMBER 1976

September 1976	Day of Week	Raw Refuse In-Feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
1	Wednesday	0	0	Change shredder hammers
2	Thursday	7.5	9.8	76.5
3	Friday	11.1	12.3	90.2
6	Monday	0	0	Labor Day holiday
7	Tuesday	0	0	Shutdown at request of power plant
8	Wednesday	2.7	3.1	87.1
9	Thursday	7.9	10.0	79.0
10	Friday	11.9	13.8	86.2
13	Monday	7.5	8.5	88.2
14	Tuesday	2.8	3.4	82.4
15	Wednesday	7.7	10.0	77.0
16	Thursday	8.2	9.8	83.7
17	Friday	6.5	7.9	82.3
20	Monday	6.5	8.8	73.9
21	Tuesday	6.4	7.5	85.3
22	Wednesday	4.5	6.0	75.0
23	Thursday	7.0	7.5	93.3
24	Friday	4.3	6.1	70.5
27	Monday	6.5	7.0	92.9
28	Tuesday	3.6	5.5	80.0
29	Wednesday	1.8	2.8	64.3
30	Thursday	6.2	9.4	66.0
Total		120.6	148.2	81.4
Average		6.35	7.8	

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[a] Recorded hours from running time meters on in-feed conveyor (C-1).

[b] Recorded hours from running time meter on pneumatic conveying feeder

TABLE C-4e. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF OCTOBER 1976

Day October 1976	Day of Week	Raw Refuse In-Feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
1	Friday	7.0	9.6	72.9
4	Monday	6.6	8.3	79.5
5	Tuesday	6.2	7.3	84.9
6	Wednesday	3.1	3.6	86.1
7	Thursday	6.5	8.7	74.7
8	Friday	7.4	9.0	82.2
11	Monday	5.7	7.0	81.4
12	Tuesday	6.8	8.4	81.0
13	Wednesday	5.5	7.6	72.4
14	Thursday	4.5	4.9	91.8
15	Friday	3.7	6.7	55.2
18	Monday	6.3	8.2	76.8
19	Tuesday	4.3	5.8	74.1
20	Wednesday	6.8	7.5	90.7
21	Thursday	4.6	5.5	83.6
22	Friday	6.4	7.5	85.3
25	Monday	6.8	8.4	81.0
26	Tuesday	4.2	4.8	87.5
27	Wednesday	3.0	4.8	62.5
28	Thursday	5.7	7.1	80.3
29	Friday	1.1	1.3	84.6
Total		112.2	142.0	79.0
Average		5.34	6.76	

[a] Recorded hours from running time meter on in-feed conveyor (C-1).

[b] Recorded hours from running time meter on pneumatic conveying feeder.

TABLE C-4f. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF NOVEMBER 1976

Day November 1976	Day of Week	Raw Refuse In-Feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
1	Monday	5.1	7.6	67.1
2	Tuesday	8.0	9.3	86.0
3	Wednesday	4.8	7.1	67.6
4	Thursday	5.2	7.1	73.2
5	Friday	6.9	8.5	81.2
6-21	Plant not operating because of fire damage			
22	Monday	2.9	3.8	76.3
23	Tuesday	1.4	2.0	70.0
24	Wednesday	6.2	8.1	76.5
25	Holiday			
26	Friday	5.0	7.4	67.6
29	Monday	3.4	6.6	51.5
30	Tuesday	5.2	9.5	54.7
Total		54.1	77.0	70.3
Average		4.92	7.00	

[a] Recorded hours from running time meter on in-feed conveyor (C-1).
[b] Recorded hours from running time meter on pneumatic conveying feeder.

TABLE C-4g. DAILY PROCESSING HOURS--REFUSE PROCESSING PLANT FOR THE MONTH OF DECEMBER 1976

Day December 1976	Day of Week	Raw Refuse In-Feed (hr)[a]	Plant Operating (hr)[b]	Use Factor (in-feed hours as percent of plant operating hours)
1	Wednesday	6.6	10.0	66.0
2	Thursday	6.9	8.6	80.2
3	Friday	6.3	8.2	76.8
6	Monday	5.1	6.7	76.1
7	Tuesday	7.5	9.0	83.3
8	Wednesday	2.9	3.6	80.6
9	Thursday	7.3	8.3	88.0
10	Friday	5.1	6.1	83.6
13	Monday	5.3	7.4	71.6
14	Tuesday	6.6	8.1	81.5
15	Wednesday	2.6	3.0	86.7
16	Thursday	8.1	8.9	91.0
17	Friday	3.7	6.5	56.9
20	Monday	7.7	12.7	60.6
21	Tuesday	8.5	9.2	92.4
22	Wednesday	4.8	5.3	90.6
23	Thursday	4.4	7.2	61.1
24	Friday	2.9	3.3	87.9
27	Monday	3.8	5.6	67.9
28	Tuesday	6.8	7.5	90.7
29	Wednesday	5.0	6.2	80.6
30	Thursday	8.7	6.0	145.0
31	Friday	3.9	5.7	68.4
Total		130.5	163.1	80.0
Average		5.67	7.09	

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[a] Recorded hours from running time meter on in-feed conveyor (C-1).

[b] Recorded hours from running time meter on pneumatic conveying feeder.

TABLE C-5. WEEKLY ELECTRIC POWER CONSUMPTION FOR REFUSE PROCESSING PLANT AND STORAGE BIN

Meter No.a/	1	2	3	4	5	5-7	(1 + 2 + 3 + 4 + 5) - 7	7	1 + 2 + 3 + 4 + 5
	Electric Power Used: kW-hr								
Week	First Stage Shredder	Second Stage Shredder	ADS Fan	Pneumatic Conveying Blower (to Storage Bin)	Storage Bin and Processing Plant Indirect	Processing Plant Indirect b/	Total Processing Plant	Storage Bin (Storage and Pneumatic Conveying to Boilers)	Total Processing Plant and Storage Bin
(June 1976)									
1-5	5,600	11,620	3,640	3,150	13,890	7,330	31,340	6,560	37,900
6-12	4,200	7,700	3,150	2,660	21,990	10,870	28,580	11,120	39,700
13-19	3,220	6,020	2,100	1,680	15,680	7,440	20,460	8,240	28,700
20-26	4,060	7,420	3,290	3,010	41,300	32,180	49,960	9,120	59,080
27-30	2,520	3,920	1,820	1,680	14,210	8,130	17,440	6,080	24,150
June total	19,600	36,680	14,000	12,180	107,070	65,950	147,780	41,120	189,530
(July 1976)									
1-3	2,520	4,620	1,680	1,330	18,095	13,135	26,120	4,960	28,245
4-10	4,200	6,020	2,660	1,960	24,690	16,330	25,080	9,260	39,530
11-17	4,620	8,820	3,010	2,730	23,765	13,925	39,720	9,840	42,945
18-24	4,760	9,100	2,870	2,450	28,840	20,200	35,040	8,640	48,020
25-30	7,560	14,000	3,780	3,290	32,885	22,845	55,640	9,040	61,515
July total	23,660	42,560	14,000	11,760	128,275	86,435	181,600	41,840	220,255
(August 1976)									
1-7	4,060	6,020	2,240	1,680	18,550	9,590	17,920	8,960	32,550
8-14	7,280	11,340	4,550	3,780	27,955	18,515	50,200	9,440	54,905
15-21	3,920	7,000	2,800	2,450	29,670	21,030	30,840	8,640	45,840
22-28	6,340	11,760	4,340	3,220	37,050	28,010	48,080	9,040	60,710
29-31	1,820	4,200	1,330	1,190	4,375	535	15,480	3,840	12,915
August total	21,420	40,320	15,260	12,320	117,600	77,680	162,520	39,920	206,920
(September 1976)									
1-4	3,360	5,600	1,960	1,610	20,370	13,810	20,320	6,560	32,900
5-11	3,500	11,900	3,010	2,450	28,700	18,220	39,920	10,480	49,560
12-18	5,180	12,460	3,710	3,150	25,385	16,105	44,480	9,280	49,885
19-25	4,760	9,240	3.150	2,940	25,865	15,965	37,120	9,920	45,955
26-30	5,040	8,960	3,430	2,590	24,535	17,975	34,600	6,560	44,555
September total	21.840	48.160	15,260	12,740	124,855	82.055	176,440	42.800	222.855

(continued)

TABLE C-5. (continued)

	Electric Power Used: KW-hr								
Meter No.[a/]	1	2	3	4	5	5-7	(1 + 2 + 3 + 4 + 5) - 7)	7	1 + 2 + 3 + 4 + 5
Week	First Stage Shredder	Second Stage Shredder	ADS Fan	Pneumatic Conveying Blower (to Storage Bin	Storage Bin and Processing Plant Indirect	Processing Plant Indirect[b/]	Total Processing Plant	Storage Bin (Storage and Pneumatic Conveying to Boilers)	Total Processing Plant and Storage Bin
(October 1976)									
1-2	280	980	420	420	4,200	1,000	3,100	3,200	6,300
3-9	4,340	7,620	3,150	2,590	30,625	20,865	38,365	9,760	48,125
10-16	5,460	8,120	3,220	2,660	22,225	15,025	34,485	7,200	41,685
17-23	5,600	8,400	3,430	3,080	32,725	23,605	44,115	9,120	53,235
24-31	5,740	5,740	2,590	2,310	32,900	19,220	35,600	13,680	49,280
October total	21,420	30,660	12,810	11,060	122,675	79,715	155,665	42,960	198,625
(November 1976)									
1-6	8,400	8,400	4,200	3,500	21,735	12,695	37,195	9,040	46,235
7-13	-0-	-0-	-0-	-0-	21,490	17,490	17,490	4,000	21,490
14-20	-0-	-0-	-0-	-0-	44,310	42,150	42,150	2,160	44.310
21-27	5,320	4.060	2,030	1,960	25,165	17,565	30,935	7.600	38,535
28-30	2,800	2,940	1,960	1,260	15,820	12,620	21,580	3,200	24,780
November total	16,520	15,400	8,190	6,720	128,520	102,520	149,350	26,000	175,350
(December 1976)									
1-4	5,040	8,400	2,870	2,170	36,295	29,415	47,895	6,880	54,775
5-11	7,840	7,140	3,430	2,520	43,295	31,455	52,385	11,840	64,225
12-18	4,480	7,280	3,640	3,010	41,790	32,110	50,520	9,680	60,200
19-25	4,480	7,280	3,850	2,800	48,230	37,110	55,520	11,120	66,640
26-31	3,780	6,580	3,080	2,310	41,675	33,235	48,985	8,240	57,225
December total	25,620	36,680	16,870	12,810	211,085	163,325	255,305	47,760	303,065

[a/] Kilowatt-hour meter number or per plant designation.
[b/] Heat, light, ventilation, air conditioning, maintenance, conveyors, feeders, and metal recovery systems.

TABLE C-6. MAJOR ELECTRIC MOTORS--REFUSE PROCESSING PLANT AND STORAGE BIN

Conveyor No.[a]	Equipment Served	kW[b]	hp	Name Plate Amperage
	3-Phase 4,160-v motors			
	First stage shredder	746	1,000	151
	Second stage shredder	746	1,000	151
	ADS fan	149.2	200	25.3
	Pneumatic conveying blower--plant to storage bin	149.2	200	26
	3-Phase 460-v motors			
C1	Raw refuse in-feed conveyor	5.60	7.5	11
C2	Shredder No. 1 discharge conveyor	5.60	7.5	11
C3	Shredder No. 2 feed conveyor	7.46	10	14
C4	Backup raw refuse feed conveyor	3.73	5	6.7
C5	Shredder No. 2 vibrating feeder conveyor	7.46	7.5	11
C6	Shredder No. 2 discharge conveyor	1.12	1.5	2.5
	Magnetic belt separator	3.73	5	7.6
	ADS flight conveyor	11.19	15	19.5
	ADS surge bin scalping roll	2.24	3	4.15
	ADS vibrating feeder	7.46	10	14
	ADS rotary airlock	11.19	15	21
	Screw conveyor	14.92	20	24.7
	Rotary airlock feeder for pneumatic conveying to storage	29.84	40	49
	Vane Pump No. 1	2.24	3	4.5
	Vane Pump No. 2	2.24	3	4.5
C7	ADS heavies conveyor	1.12	1.5	2.5
C8	ADS heavies conveyor to E1	1.12	1.5	2.5
C9	Fe-metal conveyor to C13	1.12	1.5	2.5
C10	Rejects conveyor to C11	1.12	1.5	2.5
C11	Rejects conveyor to C3	1.12	1.5	2.5
C12	Fe-metal conveyor to C13	1.12	1.5	2.5
C13	Fe-metal conveyor to storage	1.12	1.5	2.5
C14	Conveyor from E1 to C15	1.12	1.5	2.5
C15	Conveyor to rejects conveyor C16	1.12	1.5	2.5
C16	Rejects conveyor to storage	1.12	1.5	2.5
C17	Glass or rejects to storage	1.12	1.5	2.5
E1	ADS heavies bucket elevator	2.24	3	4.8
E2	Rejects bucket elevator	1.12	1.5	2.5
E3	Glass and rejects bucket elevator	1.12	1.5	2.5
E4	Aluminum bucket elevator	1.12	1.5	2.5
E5	Copper and brass bucket elevator	1.12	1.5	2.5
	Chicago pump	1.12	1.5	2.4
	Air compressor	11.19	15	20.5
	Equipment hoist	11.19	15	20.5
	Equipment trolly for hoist	0.75	1	1.8
	Equipment bridge for trolly	2.24	3	4.8
	Live bottom Hopper No. 1	3.73	5	7.6
	Live bottom Hopper No. 2	3.73	5	7.6
	Trommel screen drive	11.19	15	18.7
F2	Aluminum separation conveyor	0.25	0.33	0.75
F3	Aluminum separation conveyor	0.25	0.33	0.75
C19	Nonferrous separation conveyor	0.25	0.33	0.75
C20	Aluminum separation conveyor	0.37	0.5	1
C21	Aluminum separation rejects conveyor	0.37	0.5	1
C24	Aluminum separation conveyor	0.25	0.33	0.8
C25	Nonferrous separation conveyor	0.37	0.5	1.1
C27	Nonferrous rejects conveyor to C28	0.37	0.5	1
C28	Nonferrous rejects conveyor to E2	0.56	0.75	1.4
F6	Nonferrous separation conveyor	0.25	0.33	0.8
F7	Nonferrous separation conveyor	0.25	0.33	0.8
C29	Glass conveyor to E3	0.25	0.33	0.8
C31	Secondary aluminum separation conveyor	0.25	0.33	0.8
C32	Nonferrous conveyor	0.25	0.33	0.8
	Motor generator (exciter 30 v 5 amp, alternator 222 KVA 0.8 power factor 120/208 v 61.5 amp)	37.30	50	60

(continued)

TABLE C-6. (continued)

Conveyor No.[a]	Equipment Served	kw[b]	hp	Name Plate Amperage
	Storage bin fluffing roll A	2.24	3	4.5
	Storage bin fluffing roll B	2.24	3	4.5
	Storage bin fluffing roll C	2.24	3	4.5
	Storage bin fluffing roll D	2.24	3	4.5
	Storage bin rotary airlock feeder A	5.60	7.5	11
	Storage bin rotary airlock feeder B	5.60	7.5	11
	Storage bin rotary airlock feeder C	5.60	7.5	11
	Storage bin rotary airlock feeder D	5.60	7.5	11
	Blower for pneumatic conveyor to boiler-line A	44.76	60	77
	Blower for pneumatic conveyor to boiler-line B	44.76	60	77
	Blower for pneumatic conveyor to boiler-line C	44.76	60	77
	Blower for pneumatic conveyor to boiler-line D	44.76	60	77
	Paper bailer	37.30	50	62.5
	Paper bailer conveyor	3.73	5	6.7
	Wood chipper	93.25	125	140
	Wood chipper feed	0.56	0.75	1.1
	Wood chipper conveyor	18.65	25	32.0
	Single-Phase 120-v Motors			
C22	Aluminum separation conveyor	0.37	0.5	9.8
C23	Aluminum separation conveyor	0.37	0.5	9.6
C30	Secondary aluminum separation conveyor	0.37	0.5	9.8
	Nonferrous separation conveyor No. 1	0.37	0.5	9.8
	Nonferrous separation conveyor No. 2	0.37	0.5	9.8
	DC 240-v Motors			
	Storage bin sweep conveyor - Drive No. 1	29.84	40	138
	Storage bin sweep conveyor - Drive No. 2	29.84	40	138
	Storage bin drag conveyor A	5.60	7.5	25.8
	Storage bin drag conveyor B	5.60	7.5	25.8
	Storage bin drag conveyor C	5.60	7.5	25.8
	Storage bin drag conveyor D	5.60	7.5	25.8
	DC 90-v Motors			
Nonferrous system	Long belt drive No. 1	0.37	0.5	5.5
Nonferrous system	Long belt drive No. 2	0.37	0.5	5.5
Nonferrous system	Long belt drive No. 3	0.37	0.5	5.5
Nonferrous system	Short belt drive No. 1	0.37	0.5	5.5
Nonferrous system	Short belt drive No. 2	0.37	0.5	5.5
F1	Nonferrous system conveyor 100/200 V	0.75	1	1.2/0.6
	Subtotal	2,460.66	3,298.47	
	Power Supply			
Nonferrous system	Rectifier for magnetic belt separator	15		
	Total	2,475.65		

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[a] Conveyor No. refers to processing flow diagram.

[b] kw Basis 0.746 kw/hp. ASTM Standard E380-74, Metric Practive Guide.

TABLE C-7a. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - JUNE 1976

Day (June 1976)	Day of Week	Hours of Operation Pneumatic Conveying Line A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
2	Wed	13.3			14.0	14.0	41.9	3.0
3	Thur	16.0			18.0	18.0	71.1	4.0
4	Fri	18.0			22.0	22.0	94.0	4.3
5	Sat	20.0			24.0	24.0	74.6	3.1
6	Sun	23.5			21.8	23.5	80.2	3.4
7	Mon	13.3			14.0	14.0	65.9	4.7
8	Tues	23.5			24.0	24.0	96.5	4.0
9	Wed	(24)[a]			(24)[a]	24.0	78.3	3.3
10	Thur	23.8			24.0	24.0	87.8	3.7
11	Fri	18.3			20.2	20.2	68.6	3.4
12	Sat	24.0			23.5	24.0	91.1	3.8
13	Sun	24.0			23.8	24.0	112.3	4.7
14	Mon	21.2			17.7	21.2	85.6	4.0
15	Tues	15.2			20.2	20.2	75.2	3.7
16	Wed	13.4			6.3	13.4	21.4	1.6
17	Thur	3.9			2.3	3.9	5.8	1.5
18	Fri	9.1			5.2	9.1	41.5	4.6
19	Sat	24.0			24.0	24.0	97.0	4.0
20	Sun	24.0			18.2	24.0	90.8	3.8
21	Mon	6.8			6.7	6.8	25.4	3.7
22	Tues	14.0			13.0	14.0	50.7	3.6
23	Wed	22.0			11.6	22.0	71.4	3.2
24	Thur	13.3	9.1	0.4	17.8	17.8	70.9	4.0
25	Fri	12.4			19.0	19.0	55.1	2.9
26	Sat	24.0			24.0	24.0	109.6	4.6
27	Sun	23.4			15.7	23.4	81.6	3.5
28	Mon	23.2			18.6	23.2	70.9	3.1
29	Tues	22.7			24.0	24.0	97.9	4.1
30	Wed	23.2			15.4	23.2	66.0	2.8
Monthly Total		537.5	9.1	0.4	513.0	568.9	2,079.1	3.7[b]
Use Factor %[c]		77.2	1.3	0.06	73.7	81.7		

[a] Data not recorded. Estimated 24 hr.

[b] Total Mg/total hours. Not arithmetic average of Mg/Hr.

[c] % of available hours. Available hours = 29 days (24 hr/day) = 696 hr.

TABLE C-7b. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - JULY 1976

Day (July 1976)	Day of Week	Hours of Operation Pneumatic Conveying Line				Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
		A	B	C	D			
1	Thur	20.9			23.6	23.6	84.4	3.6
2	Fri	24.0			23.1	24.0	99.8	4.2
3	Sat	22.3			23.1	23.1	86.4	3.7
4	Sun	22.2			24.0	24.0	97.3	4.1
5	Mon	23.9			0	23.9	95.7	4.0
6	Tues	2.7			24.0	24.0	16.2	0.7
7	Wed	15.3			24.0	24.0	97.6	4.1
8	Thur	19.5			23.9	23.9	76.3	3.2
9	Fri	19.3			18.7	19.3	91.9	4.8
10	Sat	24.0			23.9	24.0	103.3	4.3
11	Sun	17.6			24.0	24.0	105.5	4.4
12	Mon	11.9			11.9	11.9	36.9	3.1
13	Tues	22.0			23.0	23.0	100.4	4.4
14	Wed	18.6			24.0	24.0	84.8	3.5
15	Thur	22.6			15.8	22.6	95.1	4.2
16	Fri	22.1			17.8	22.1	83.2	3.8
17	Sat	24.0			24.0	24.0	121.3	5.1
18	Sun	23.4			23.7	23.7	115.9	4.9
19	Mon	2.6			2.7	2.7	9.3	3.4
20	Tues	22.2			24.0	24.0	85.6	3.6
21	Wed	17.4			17.6	17.6	64.7	3.7
22	Thur	4.5			4.4	4.5	29.9	6.7
23	Fri	22.6			22.7	22.7	111.4	4.9
24	Sat	20.8			21.4	21.4	83.4	3.9
25	Sun	22.2			20.6	22.2	84.5	3.8
26	Mon	11.6			11.3	11.6	36.4	3.1
27	Tues	11.1			10.7	11.1	32.7	3.0
28	Wed	23.9			23.9	23.9	117.6	4.9
29	Thur	21.3			9.4	21.3	71.4	3.4
30	Fri	9.2		0.3	7.5	9.2	45.0	4.9
31	Sat	22.2	0.2		17.5	22.2	81.6	3.7
Monthly Total		567.9	0.2	0.3	566.2	623.5	2,445.5	3.9[a]
Use Factor[b]		76.3%	0	0	76.1	83.8		

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[a] Total Mg/total hours. Not arithmetic average of Mg/hr.

[b] Percent of available hours. Available hours = 31 days x 24 hr/day = 744 hr.

TABLE C-7c. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - AUGUST 1976

Day (August 1976)	Day of Week	Hours of Operation Pneumatic Conveying Line A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
1	Sun	24.0		0.4	24.0	24.0	110.3	4.6
2	Mon	9.3		0.2	7.2	9.3	30.8	3.3
3	Tues	6.1			6.7	6.7	9.5	1.4
4	Wed	23.8			23.8	23.8	102.6	4.3
5	Thur	14.8			14.6	14.8	78.0	5.3
6	Fri	16.6			23.5	23.5	106.5	4.5
7	Sat	21.3			21.6	21.6	103.7	4.8
8	Sun	23.0			22.8	23.0	115.8	5.0
9	Mon	13.1			14.0	14.0	57.9	4.1
10	Tues	22.5			13.9	22.5	109.5	4.9
11	Wed	22.6			9.7	22.6	126.3	5.6
12	Thur	24.0			9.8	24.0	126.9	5.3
13	Fri	24.0	0.5	0.5	24.0	24.0	159.6	6.7
14	Sat	17.3			23.8	23.8	101.6	4.3
15	Sun	24.0			24.0	24.0	172.3	7.2
16	Mon	9.7			9.5	9.7	68.0	7.0
17	Tues	24.0	0.3	0.3	24.0	24.0	124.4	5.2
18	Wed	8.3	0.2	0.1	9.1	9.1	34.9	3.8
19	Thur	23.8		0.1	23.9	23.9	103.6	4.3
20	Fri	15.0		0.2	12.2	15.0	50.4	3.4
21	Sat	23.4			23.4	23.4	96.0	4.1
22	Sun	19.0			24.0	24.0	106.1	4.4
23	Mon	18.0			18.0	18.0	64.1	3.6
24	Tues	3.8			4.2	4.2	14.9	3.5
25	Wed	15.5			11.1	15.5	31.9	2.1
26	Thur	23.9			23.3	23.9	88.4	3.7
27	Fri	13.8	2.2	2.7	14.2	14.2	39.5	2.8
28	Sat	23.9			23.7	23.9	79.3	3.3
29	Sun	23.7			19.8	23.7	93.1	3.9
30	Mon	22.3			0.1	22.3	43.9	2.0
31	Tues	23.7			4.0	23.7	47.9	2.0
Monthly Total		578.2	3.2	3.9	507.9	600.1	2,597.7	4.3
Use Factor[b]		77.7%	0.4%	0.5%	68.3%	80.7%		

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a/ Total Mg/total hours. Not arithmetic average of Mg/hr.

b/ Percent of available hours. Available hours = 31 days x 24 hr/day = 744 hr.

TABle C-7d. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - SEPTEMBER 1976

		Hours of Operation Pneumatic Conveying Line						
(September 1976)	Day of Week	A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
1	Wed	13.7			23.7	23.7	103.4	4.4
2	Thur	19.0			21.6	21.6	86.0	4.0
3	Fri	23.0			23.0	23.0	101.6	4.4
4	Sat	16.1			23.6	23.6	89.6	3.8
5	Sun	20.9			23.7	23.7	96.9	4.1
6	Mon	19.4			14.6	19.4	78.2	4.0
7	Tues	21.3			17.2	21.3	85.2	4.0
8	Wed	22.1			24.0	24.0	127.0	5.3
9	Thur	22.3			23.1	23.1	82.7	3.6
10	Fri	23.8			23.1	23.8	97.3	4.1
11	Sat	24.0			24.0	24.0	105.1	4.4
12	Sun	14.5			14.4	14.5	46.5	3.2
13	Mon	13.3			13.7	13.7	79.3	5.8
14	Tues	16.1			16.2	16.2	49.5	3.1
15	Wed	22.7			22.6	22.7	90.0	4.0
16	Thur	23.9			23.9	23.9	101.0	4.2
17	Fri	24.0			24.0	24.0	105.6	4.4
18	Sat	24.0			24.0	24.0	92.9	3.9
19	Sun	15.0			15.0	15.0	54.8	3.7
20	Mon	15.0			13.1	15.0	53.9	3.6
21	Tues	19.6			22.7	22.7	86.1	3.8
22	Wed	24.0			23.9	24.0	93.0	3.9
23	Thur	22.6			23.6	23.6	93.2	4.0
25	Sat	20.2			24.0	24.0	93.7	3.9
26	Sun	16.8			16.8	16.8	55.5	3.3
27	Mon	16.7			16.7	16.7	60.2	3.6
28	Tues	23.9			24.0	24.0	69.0	2.9
29	Wed	7.4			24.0	24.0	65.0	2.7
30	Thur	6.2			24.0	24.0	28.9	1.2
Monthly Total		575.7			632.1	643.9	2,464.4	3.8[a]
Use Factor[b]		80.0%			87.8%	89.4%		

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a/ Total Mg/total hours. Not arithmetic average of Mg/hr.

b/ Percent of available hours. Available hours = 30 days x 24 hours/day = 720 hours.

TABLE C-7e. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - OCTOBER 1976

		Hours of Operation Pneumatic Conveying Line						
(October 1976)	Day of Week	A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
1	Fri	22.3			23.6	23.6	94.6	4.0
2	Sat	24.0			24.0	24.0	83.1	3.5
3	Sun	20.2			20.2	20.2	64.8	3.2
4	Mon	14.9			14.0	14.9	53.6	3.6
5	Tues	19.9			19.8	19.9	65.8	3.3
6	Wed	15.7			15.6	15.7	52.0	3.3
7	Thur	21.7			24.0	24.0	76.9	3.2
8	Fri	24.0			24.0	24.0	113.6	4.7
9	Sat	24.0			24.0	24.0	119.4	5.0
10	Sun	23.9			23.9	23.9	97.5	4.1
11	Mon	19.7			19.7	19.7	64.2	3.3
12	Tues	22.8			23.4	23.4	88.9	3.8
13	Wed	24.0			24.0	24.0	101.9	4.2
14	Thur	3.7			4.6	4.6	14.4	3.1
15	Fri	0			1.3	1.3	2.0	1.5
16	Sat	2.4			3.0	3.0	5.0	1.7
17	Sun	14.8			13.0	14.8	49.8	3.4
18	Mon	22.1			23.8	23.8	99.7	4.2
19	Tues	24.0			24.0	24.0	107.2	4.5
20	Wed	23.6			23.6	23.6	109.5	4.6
21	Thurs	22.7			21.0	22.7	101.9	4.5
22	Fri	23.4			23.6	23.6	109.5	4.6
23	Sat	23.4			23.4	23.4	120.19	5.1
24	Sun	23.5			23.3	23.5	104.8	4.5
25	Mon	24.0			24.0	24.0	119.0	5.0
26	Tues	23.7			23.3	23.7	118.3	5.0
27	Wed	24.0			24.0	24.0	121.6	5.1
28	Thur	24.0			23.0	24.0	116.1	4.8
29	Fri	23.5			20.5	23.5	86.4	3.7
30	Sat	22.2			15.9	22.2	88.6	4.0
31	Sun	23.8			23.8	23.8	133.8	5.6
Monthly T								
Monthly total		625.9			619.3	634.8	2684.0	4.2[a]
Use factor %[b]		84.1			83.2	85.3		

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[a] Total Mg/total hours. Not arithmetic average of Mg/Hr.

[b] % of available hours. Available hours = 31 days (24 hr/day) = 744 hr.

TABLE C-7f. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - NOVEMBER 1976

		Hours of Operation Pneumatic Conveying Line						
(November 1976)	Day of Week	A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
1	Mon	14.2			14.0	14.2	62.5	4.4
2	Tues	23.9			23.8	23.9	86.5	3.6
3	Wed	23.7			23.8	23.8	100.4	4.2
4	Thur	23.2			22.8	23.2	98.5	4.2
5	Fri	24.0			24.0	24.0	121.0	5.0
6	Sat	24.0			24.0	24.0	121.7	5.1
7	Sun	24.0			24.0	24.0	106.9	4.5
8	Mon	8.0			7.9	8.0	24.7	3.1
9-22	System down for fire damage and repair							
23	Tues	10.1			10.0	10.1	30.2	3.0
24	Wed	12.4			23.6	23.6	74.1	3.1
25	Thur	23.6			24.0	24.0	93.7	3.9
26	Fri	23.3			23.4	23.4	175.7	7.5
27	Sat	24.0			24.0	24.0	135.9	5.7
28	Sun	6.8			6.8	6.8	35.0	5.1
29	Mon	11.7			11.0	11.7	38.7	3.3
30	Tues	23.9			21.1	23.9	90.9	3.8
Monthly total		300.8			308.2	312.6	1,396.4	4.5[a]
Use factor[b]		41.8%			42.8%	43.4%		
Use factor[c]		78.3%			80.3%	81.4%		

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a/ Total Mg/total hours. Not arithmetic average of Mg/Hr.
b/ % of available hours. Available hours = 30 days (24 hr/day) = 720 hr.
c/ % of available hours less downtime for fire damage 16 days (24 hr/day) = 384 hr.

TABLE C-7g. PNEUMATIC CONVEYING FROM STORAGE BIN TO BOILERS OPERATING HOURS AND AMOUNT OF RDF BURNED - DECEMBER 1976

		Hours of Operation Pneumatic Conveying Line						
(December 1976)	Day of Week	A	B	C	D	Hours RDF Burned	RDF Burned (Mg)	Average Burn Rate (Mg/hr)
1	Wed	24.0			24.0	24.0	98.9	4.1
2	Thur	24.0			24.0	24.0	88.9	3.7
3	Fri	24.0			24.0	24.0	122.1	5.1
4	Sat	21.2			23.2	23.2	106.4	4.6
5	Sun	23.6			24.0	24.0	112.4	4.7
6	Mon	21.2			24.0	24.0	90.9	3.8
7	Tue	24.0			24.0	24.0	127.4	5.3
8	Wed	24.0			24.0	24.0	84.2	3.5
9	Thur	21.1			21.7	21.7	99.5	4.6
10	Fri	24.0			24.0	24.0	104.8	4.4
11	Sat	21.5			24.0	24.0	103.0	4.3
12	Sun	8.6			8.9	8.9	30.0	3.4
13	Mon	10.9			1.2	10.9	21.8	2.0
14	Tue	18.6			11.7	18.6	56.1	3.0
15	Wed	20.8			22.4	22.4	73.8	3.3
16	Thur	23.9			23.8	23.9	79.4	3.3
17	Fri	15.5			23.6	23.6	61.6	2.6
18	Sat	21.8			23.0	23.0	62.5	2.7
19	Sun	23.5			23.6	23.6	24.7	1.0
20	Mon	17.9			19.8	19.8	34.7	1.8
21	Tue	19.3			24.0	24.0	72.9	3.0
22	Wed	15.6			17.4	17.4	51.2	2.9
23	Thur	14.4			14.5	14.5	101.7	7.0
24	Fri	12.2			16.7	16.7	53.3	3.2
25	Sat	22.4			23.1	23.1	83.9	3.6
26	Sun	6.0			5.9	6.0	18.5	3.1
27	Mon	10.9			9.3	10.9	41.0	3.8
28	Tues	22.9			21.4	22.9	78.5	3.4
29	Wed	21.2			14.0	21.2	65.6	3.1
30	Thur	17.0			20.0	20.0	56.7	2.8
31	Fri	24.0			24.0	24.0	83.2	3.5
Monthly totals		600.0			609.2	636.3	2,289.6	3.6[a]
Use factor[b]		30.6%			81.9%	85.5%		

[a] Total Mg/total hours. Not arithmetic average of Mg/Hr.

[b] % of available hours. Available hours = 31 days (24 hr/day) = 744 hr.

TABLE C-8a. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - JUNE 1976 (Lines A, B, C, D from storage bin to boilers)

Day (June 1976)	Line	Location	Description
2	A	Feeder	Jammed
3	A	Feeder	Jammed twice (piece of rubber tire)
	D	Elbow D2	Leak
4	A	Before Boiler 6	Leak
	A	Elbow A8	Leak
	D	Elbow D1	Plugged due to piece of wood
	D		Airlock feeder jammed Replace V-belt drive
5	A	Line	Plugged due to 457 x 914 mm piece of sheet metal
	D	Fluffing roll	Jammed
6	A	Elbow A1	Leak
	D	Elbow D1	Leak
7	A	Diverter	Repaired and installed new feeder knife
	D	Feeder	Installed new feeder knives
8	A	Before Boiler 6	Leak
	A	Elbow A2	Plugged
	D		Leak at diverter
9	A	Feeder	Jammed
	A and D	System	Change wear plate

(continued)

TABLE C-8a. (continued)

Day	Line	Location	Description
(June 1976)			
10	A	Feed chute	Plugged
	D	Elbow D2	Plugged
11	A	Elbow A2	Replaced elbow
	A	Drive	New rubber spider installed in direct coupling
	A	Drag conveyor	Zero-speed switch malfunctioned
12	A	System	Leak
	A	Line	Plugged between elbows A2 and A3
	D	System	Leak
13			None
14	A	Line	Plugged
	D	Feeder	Jammed
	D	System	Plugged. Motor overload circuit activated
15	A	Feeder	Jammed due to roller from sweep conveyer
	D	Diverter	Plugged
16	D	Line	Leak
17			Storage bin down
18			Sweep conveyor off
	D	Line	Leak
19	D	Elbow D4	Leak
20	D	Diverter	Plugged three times due to large pieces of plastic
21			Storage bin down

(continued)

TABLE C-8a. (continued)

Day	Line	Location	Description
(June 1976)			
22	A	Flange on spool piece at Boiler 7	Leak
	D	Feeder	Jammed and motor overload circuit activated
23	A	Feeder	Jammed (twice)
	A	System	Leak (twice) shut down to repair holes
	D	System	Plugged
		Feeder	Jammed due to tire inner-tube
24	A	Line	Install new length of line at storage bin
		Diverter	Plugged due to large pieces of plastic and cloth
			(Note: Both A and D lines shut down twice due to low boiler steam pressure)
25	A	Elbow A6	Plugged
	A	System	Line shut down due to poor boiler combustion
	D	Line	Install new length of line at storage bin
	D	System	Plugged
26	D	Diverter	Leak
27	A	System	Jammed
	D	Diverter	Plugged due to plywood, plastic and wire

(continued)

TABLE C-8a. (continued)

Day	Line	Location	Description
(June 1976)			
28	A	System	Plugged due to plastic and wood
	A	Elbow A6	Hole
	D	Line	Leak
29	A	System	Off for maintenance
	A	Elbow A7	Plugged
	A	Line	Leak
	D	Drag conveyor	Roller on drag conveyor froze
30	A	System	Off for maintenance
	D	Feeder	Fluffing roll not operative New knife installed in feeder
	D	System	Plugged

TABLE C-8b. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - JULY 1976 (Lines A, B, C, D from storage bin to boilers)

Day (July 1976)	Line	Location	Description
1	A	Feeder	Installed new knife and new flange gasket
	D	Feed conveyor	Motor overload circuit activated
	D	Diverter	Lubrication and patch two holes
2	D	Feed conveyor	Motor overload circuit activated
		Feeder	Installed new knife blades
3	A	Elbow A7	Plugged twice
	D	Diverter	Plugged
4	A	Feeder	Jammed
	A	Elbow A7	Plugged due to wood and plastic
	D	Line	Plugged twice
5	A	Elbow A7	Plugged
	A	Elbow A7	Leak
	D	Line	Plugged
6	A	Elbow A7	Leak
	A	Diverter	Plugged
7	A	Elbows A2 and A3	New experimental elbow installed at A2 and old A2 elbow installed at A3
	D	Line	Leak
8	A	Elbow A7	Plugged three times
	D	Feeder	Plugged
	D	Diverter	Plugged
9		Storage bin	Changed elbow immediately before receiving cyclone on pneumatic line from processing plant to storage bin

(continued)

TABLE C-8b. (continued)

Day	Line	Location	Description
(July 1976)			
10	D	Line	Leaks
11	A	Elbow A1	Leak
	A	Diverter	Plugged
	A	Elbow A7	Plugged due to wood and plastic
12		Processing plant	Leak in elbow at processing plant
13	A and D	Feeder	Replace feeder knife
	A	Elbow A6	Plugged four times
14	A	Elbow A9	Plugged four times
	A	Before Boiler 6	Leak
15	A	Elbow A7	Replaced wear back
	D	Diverter	Plugged twice due to wood
16	D	Before Boiler 5	Hole in chute into boiler
17			None
18			None
20	A	Elbow A1	Leak
	A	Elbow A9	Plugged
21	A	System	Shut down for general maintenance
22			None

(continued)

TABLE C-8c. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - AUGUST 1976 (Lines A, B, C, D from storage bin to boilers)

Day	Line	Location	Description
(August 1976)			
2	A	Elbow A9	Maintenance
3	A	Feeder	Plugged
4	A and D	System	Shut down for maintenance
	D	Elbow before Boiler 6	Leak in wear back plate
6	A	Before Boiler 6	Leak
	A	Feeder	Plugged
	D	Elbow D8	Leak
7	A	Feeder	Plugged
	D	Line	Leaks
9	A	Diverter	Replaced diverter with straight length of pipe
		Instrumentation	Counter not working. Shut down for 1 hr to check counter
10	A	Line	Plugged
	D	Line	Leak
11	A	Line	Plugged
		Elbow A8	Repair
	D	Line	Plugged
	D	Instrumentation	Counter not working
	A and D	Feeder	Installed new feeder knives
12	D	Elbow D8	Leak
13			None
14	A and D	System	Shut down for maintenance

(continued)

TABLE C-8c. (continued)

Day (August 1976)	Line	Location	Description
15			None
16	A	Elbow A4	Repair
	D	Elbow D8	Leak
17			None
19	A	System	0.3 hr downtime for maintenance
	D	Line	Plugged (0.1 hr downtime)
21	A	Feeder	Jammed
22	D	Line	Plugged twice
23	A and D	System	General maintenance
	A	Line	Leak and plugged 3 times
	D	Line	Plugged by piece of rubber tire
	A	Line between elbows A7 and A8	Plugged
24	A	Feeder	Maintenance and installed new feeder knives
25	A	Feeder	Jammed twice
	D	Feeder	Jammed
26	A	Line	Plugged
27	A	System	Plugged
28	A	Feeder	Jammed
29	D	Fluffing roll	Out of service
	D	Feeder	Jammed 4 times
	A	Feeder	Jammed
30	A	Feeder	Jammed
31	A and D	Feeder	Jammed

TABLE C-8d. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - SEPTEMBER 1976 (Lines A, B, C, D from storage bin to boilers)

Day	Line	Location	Description
(September 1976)			
1			None
2	A	Feeder	Jammed with rubber
	A	Line	Jammed with rubber
	A	Feeder	Jammed
	D	Elbow D7	Leak
3	A	Line	Jammed
	A	Feeder	Plugged with board
	A	Feeder	Plugged
4	A	Feeder	Jammed
	A	NA	Plugged with tire
	A	Feeder	Jammed with wire
	D	Line	Leak
	D	Elbow D3	Leak
5	A	Feeder	Plugged with tire
	A	Feeder	Plugged with rubber
	D	Feeder	Plugged with tire
6	A	Feeder	Jammed
	A	Feeder	Plugged with tire
	A	Feeder	Plugged with rubber
	A	Feeder	Jammed
	D	Feeder	Jammed
	D	Feeder and line at bin	Plugged with rubber and wood
	D	Feeder	Jammed
7	A	Feeder	Plugged with rubber
	A	Feeder	Plugged with rubber
	A	Feeder	Plugged with tire and wire
	D	Feeder	Plugged with rubber

(continued)

TABLE C-8d. (continued)

Day	Line	Location	Description
(September 1976)			
8	A	Feeder	Plugged with wire
	A	Feeder	Plugged with rubber
	A	Feeder	Jammed with wire
	A	Feeder	Jammed
9	A	Elbow A4	
10	D	Elbow D3	Maintenance: welded elbow
11			None
12			None
13			None
14			None
15			None
16			None
17			None
18			None
19			None
20	A	Feeder	Jammed with belting
	D	Line	Leak
21	A	Feeder	Jammed with rubber
	D	Feeder	Jammed causing motor overload
22	D	Line	Leak

(continued)

TABLE C-8d. (continued)

Day	Line	Location	Description
(September 1976)			
23			None
24	D	Feeder	Installed new knife blade
25	A	Feeder	Jammed
	A	Feeder	Jammed with rubber
26			None
27			None
28			None
29	A	System	General maintenance
30	A	System	General maintenance

TABLE C-8e. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - OCTOBER 1976 (Lines A, B, C, D from storage bin to boilers)

Day	Line	Location	Description
(October 1976)			
1	A	Line	Leak
2			None
3			None
4	D	Feeders	Jammed with steel bar
5			None
6			None
7	A	Instrumentation	Adjust new set point system
	A	Line	Plugged due to electrical failure
	D	Instrumentation	Adjust new set point system
8	A	Feeder	Jammed
9			None
10	A	Out-feed conveyor	Stopped, restarted
11			None
12	A	A3 Elbow	Leak
	D	Line	Plugged with rubber
	A	Line	Plugged with tires
13			None
14			None
15			None
16			None

(continued)

TABLE C-8e. (continued)

Day	Line	Location	Description
(October 1976)			
17	A	Line	Plugged with rubber
	D	Line	Plugged with rubber
	D	Feeder	Jammed
18	A	Line	Plugged with rubber
	A	Line	Plugged with carpeting
	D	Line	Plugged
19	A	Feeder	Jammed with steel
	A	Feeder	Jammed with rubber
	D	Feeder	Jammed with rubber
20			None
21	A	A7 Elbow	Leak
	D	D4 Elbow	Leak
	D	D4 Elbow	Leak
	A	Feeder	Jammed
22	A		Off for repair
	D	D8 Elbow	Leak
23	A		Off for general maintenance
	D		Off for general maintenance
24			None
25			None
26	A	A8 Elbow	Leak
	A	Line	Plugged
27	A	Feeder	Jammed
28			None
29	A	A8 Elbow	Replaced
	D	D4 Elbow	Plugged
		D8 Elbow	Plugged

(continued)

TABLE C-8e. (continued)

Day	Line	Location	Description
(October 1976)			
30	A	Conveyor	Jammed with wire and wood
	D		Hi/Lo pressure valve tripped
	D	Line	Plugged
31	A	Line	Plugged with innertube
	A	Feeder	Plugged with rubber
	D		Jammed with wire
	D		Jammed with sticks

TABLE C-8f. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - NOVEMBER 1976 (Lines A, B, C, D from storage bin to boilers)

Day	Line	Location	Description
(November 1976)			
1	A	Feeder	Jammed with rubber
2	D	Elbow D-3	Leak
	D	Feeder	Jammed
3	A	Out-feed conveyor	Jammed
	D	Line	Leak
4	A	Feeder	Replace knife blades
	A	Fluffing roll	Cleaned
	D	Feeder	Replace knife blades
	D	Fluffing roll	Cleaned
5			None
6-21	All	System	Not operating because of November 6 fire in processing plant.
22			None
23			None
24	A	Feeder	Jammed
	A	Feeder	Replace knife blades
	A	A4-A5	New spool
	D	Feeder	Replace knife blades
25	A	Feeder	Jammed
26			None
27			None
28	D	At boiler No. 6	Leak
30	A	Elbow A-9	Leak
	D	Out-feed conveyor	Jammed

TABLE C-8g. DAILY RECORD OF PNEUMATIC CONVEYING DOWNTIME AND MAINTENANCE - DECEMBER 1976 (Lines A, B, C, D from storage bin to boilers)

Day	Line	Location	Description
(December 1976)			
1	D	System	Shut down for general maintenance
	D	Feed conveyor	Jammed
2	D	System	Shut down for general maintenance
4	A	Line	Plugged
	D	Line	Plugged
6	A	Line	Repair leak
8	A	System	Shut down for general maintenance
	A	Feeder	Jammed
9	A	Feeder	Jammed
	A	System	Shut down for testing purposes
10	A	Feeder	Installed new feeder knives
	D	Feeder	Installed new feeder knives
	A	Feeder	Jammed due to rubber tire
11	A	System	Jammed
13	D	System	Not operating properly
14	A	Feeder	Jammed
	A	Feeder	Jammed due to wire
	A	Line	Plugged
	D	System	Not operating properly
15	A	System	Shut down for adjustments
	A	Feeder	Jammed with rubber
	A	Feeder	Jammed with wire
	A	Feeder	Jammed with wire
	D	System	Shut down for adjustments
17	A	Feeder	Jammed
	A	Feeder	Jammed with rubber
20	A	Feeder	Motor overload circuit activated
	A	Feeder	Motor overload circuit activated

(continued)

TABLE C-8g. (continued)

Day	Line	Location	Description
(December 1976)			
21	A	Line	Chute into No. 6 boiler plugged
	A	Feeder	Jammed
22	A	Feeder	Jammed
	A	System	Shut down to replace feeder knives and to divert RDF to No. 6 boiler from No. 5
23	D	System	Shut down to replace feeder knives. Installed new spool at bin wall and repaired elbow D-8.
24	A	Line	Plugged
	D	Line	Plugged
25	A	Feeder	Jammed
27	A	Elbow A-8	Repaired
	D	Elbow D-8	Repaired
28	A	Line	Plugged
29	A	System	General maintenance
	D	System	General maintenance
30	A	System	Down. No reason given.

TABLE C-9. DAILY RECORD OF STORAGE BIN DOWNTIME AND MAINTENANCE

Day (June 1976)	Description
16	Sweep drive broke down. Replaced cam follower.
17	Sweep drive broke down. Replaced 4 verticle rollers.
18	Sweep drive broke down. Replaced thrust wheel.
21	General maintenance on sweep drive.
23	Clean up.
24	Clean up and general maintenance.
25	Problems with sweep drive.
26	General maintenance on sweep drive.
27	Problems with sweep drive.
28	Clean up and general maintenance.
29	Clean up.
30	Clean up and general maintenance. Electrical maintenance on sweep drive.
(July 1976)	
1	Repaired lubricators.
2	Installed cat-walk on top of bin.
6	Clean up. Repaired cat-walk on top of bin.
7	Clean up.
9	Clean up.
12	Clean up and full inspection of storage bin.
13.	Clean up.
14	Cleaned trap in pneumatic conveying blower.
15	Clean up and full inspection of storage bin.

(continued)

TABLE C-9. (continued)

Day (August 1976)	Description
1	Sweep drive broke down
2	Sweep drive stopped, timer off
3	Repair sweep drive
5	Sweep drive broke down, weight fell off tension pulley
6	Repair weight cable on sweep drive
7	Weight cable on sweep drive broken
8	Weight cable on sweep drive broken
10	Weight fell off cable on sweep drive
16	Sweep drive maintenance
18	Sweep drive maintenance
20	Broken chain on sweep drive
22	Sweep drive off 5 cm on out feed conveyor
29	Sweep drive down
(September 1976)	
1	Minor fire from welding
8	Bin empty
9	Bin empty
12	Bin empty
13	Bin empty
14	Bin empty
15	Bin empty
19	Bin empty
20	Bin empty
23	Repair balance cable on sweep drive
26	Bin empty
27	Bin empty

(continued)

TABLE C-9. (continued)

Day (October 1976)	Description
5	Modification to system
6	Sweep drive timer went out
18	Sweep drive stopped for maintenance
(November 1976)	
No failures occurred this month	
(December 1976)	
8	Leak in storage bin
12	Bin empty
13	Bin empty part of day
18	Sweep drive weight fall off
19	Bin empty part of day
20	Bin empty part of day
24	Stopped to clean clinkers from No. 6 boiler
25	Shut down for reasons other than equipment malfunction
26	Bin empty part of day
27	Bin empty part of day
28	Maintenance on sweep drive deflector plate
29	Bin empty part of day
30	Shut down to change diverter from boiler No. 6 to No.5

APPENDIX D - CAPITAL EXPENDITURES AMES, IOWA, SOLID WASTE RECOVERY SYSTEM

TABLE D. CAPITAL EXPENDITURES - AMES, IOWA, SOLID WASTE RECOVERY SYSTEM

Refuse Processing Plant	($)
Equipment:	
Shredders, 5 conveyors associated with shredders and ferrous metals separator	373,282
Air density separator system	182,854
Pneumatic conveying system to storage bin	30,017
Raw refuse scale system	32,769
Plant conveyors other than 5 units associated with the shredders	104,600
Nonferrous metal separation system	251,130
Plant hoist to move equipment	24,520
Electric substation including 4160 V. transformer	44,636
Motor starters and electrical disconnectors for 4160 V motors	52,707
Wood chipping machine	32,319
Total equipment	1,128,834

The estimated useful life of this class of assets is considered to be 12 yr, with no salvage value, in accordance with guidelines established by the Internal Revenue Service.[a] Annual depreciation is $91,376, or $7,615/month, on a straight line basis.

Building and Apparatus:	
Excavations, foundations, concrete, and plant building	1,515,589
Reinforcing steel	250,934
Masonry	5,727
Miscellaneous metal	164,768
Carpentry	20,534
Doors and frames	23,112
Mechanical	414,105
Electrical	314,020
Subtotal	2,708,789
Engineering	278,903
Total capital cost - refuse processing plant	4,116,526

(continued)

TABLE D. (continued)

Refuse Processing Plant	($)
The estimated useful life of this asset is 45 yr, in accordance with Internal Revenue Service guidelines. The asset is considered to have no salvage value. Annual depreciation is $90,760, or $7,563/month on a straight line basis.	
RDF Storage and Firing Facility	
Equipment:	
Storage bin	413,353
Pneumatic conveying systems to boilers	120,068
Boiler modifications	178,989
Electric substation	28,797
Total equipment	741,206
Construction:	
Storage bin excavation and concrete	137,939
Pneumatic conveying vault excavation and concrete	14,303
Reinforcing steel	83,645
Masonry	1,909
Miscellaneous metal	8,672
Carpentry	5,133
Doors and frames	5,778
Mechanical	188,479
Electrical	314,070
Subtotal	759,928
Engineering	97,993
Total capital cost RDF storage and firing facility	1,599,127

This class of assets is considered to have an estimated useful life of 20 yr, with no salvage value, in accordance with Internal Revenue Service guidelines. Annual depreciation is $79,956, or $6,663/month on a straight line basis.

(continued)

TABLE D. (continued)

RDF Storage and Firing Facility	($)
Miscellaneous Equipment:	
Tools, front end loader, trailers, etc.	164,827

These assets are considered to have an estimated useful life of 6 yr with no salvage value in accordance with Internal Revenue Service guidelines. Annual depreciation is $27,471, or $2,289/month on a straight line basis.

Land:	
City block for processing plant	82,841
Additional 10 acres at existing city landfill	15,000
Land improvements (streets, sewers, etc.)	10,000
Total land	108,068
Start-up expenses:	
Operating cost (July 1-December 31, 1975)	71,603
Interim financing cost (interest only)	21,511
Cost of bond insurance	10,139
Interest expense on bond issue[a] (March 1-December 1, 1975)	218,325
Total start-up	321,578

This asset class is considered to be amortizable over a period of 5 yr. There is no known Internal Revenue Service guideline; the period selected is based upon accepted industry practice. Annual amortization is $64,315, or $5,359/month on a straight line basis.

Grand total capital cost	6,310,126

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[a] Debentures: $5,300,000 principal amount at 5.3% interest, serialized for redemption over a 20-yr period, City of Ames Municipal Bonds Redemption Schedule. Principle payments are due annually on December 1 in accordance with the following schedule:

1976-1979	$200,000
1980-1994	$300,000

Interest is payable semiannually on June 1 and December 1.